DAZZLING MILKY WAY STAR CLOUD PICTORIAL GALLERY – PAGE 74

Astronomy®

AMERICA'S BEST-SELLING ASTRONOMY MAGAZINE

October 2002

The Universe Takes Shape

Cosmology Unveils Space-time's Architecture

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Foldout: A stunning collision between two galaxies comprises "The Mice," NGC 4676, in Coma Berenices. The universe is rife with such galactic mergers; astronomers are now not only getting a handle on small scales, like individual galaxies, but also are visualizing how the architecture of the entire cosmos may be structured. See "The Universe Takes Shape" on page 34 for the story of this rapidly developing branch of cosmology. NASA/STScI

The Meade® 30th anniversary special:

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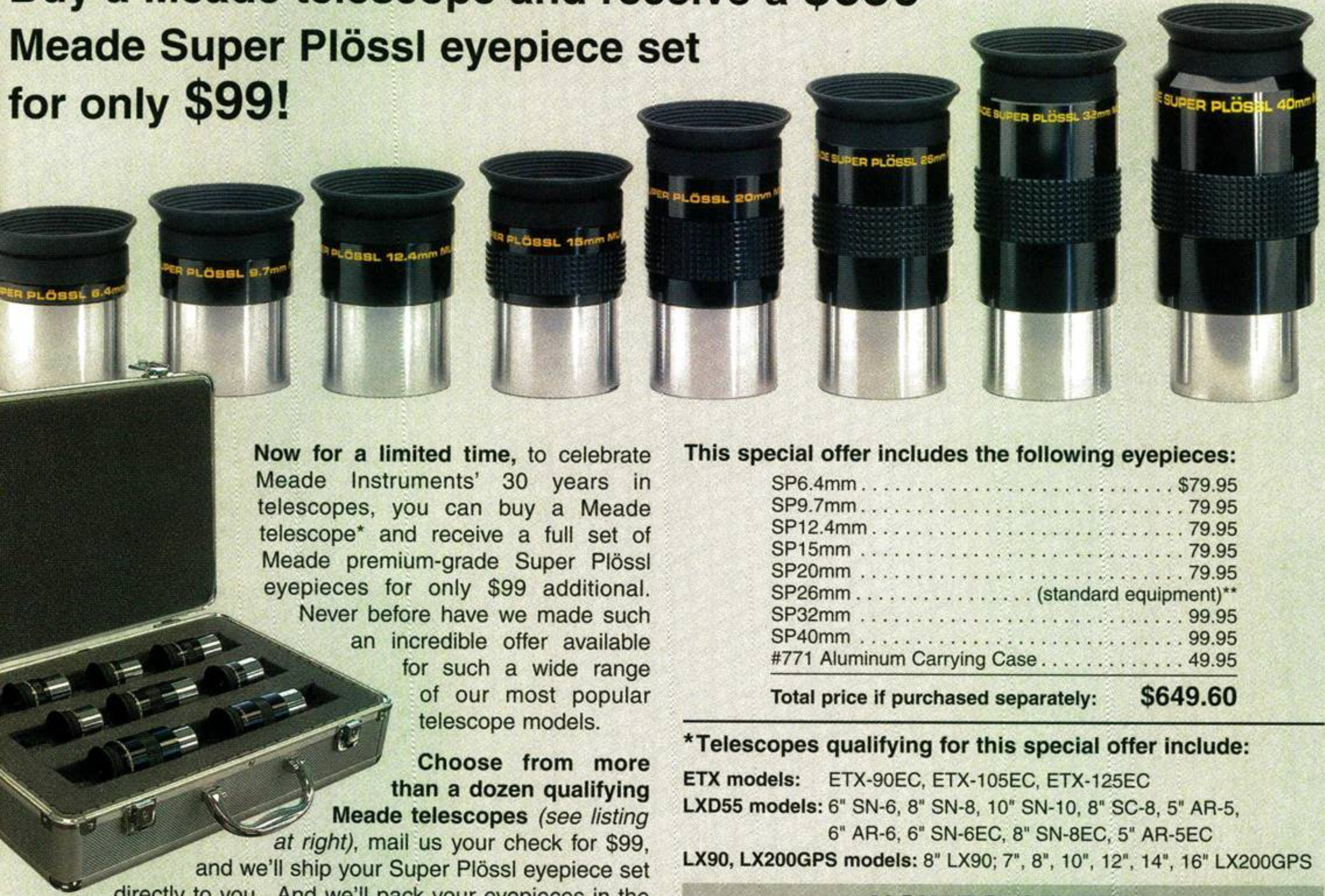
Buy a Meade telescope and receive a $650 Meade Super Plössl eyepiece set for only $99!



Now for a limited time, to celebrate Meade Instruments' 30 years in telescopes, you can buy a Meade telescope* and receive a full set of Meade premium-grade Super Plössl eyepieces for only $99 additional. Never before have we made such an incredible offer available for such a wide range of our most popular telescope models.

Choose from more than a dozen qualifying Meade telescopes *(see listing at right)*, mail us your check for $99, and we'll ship your Super Plössl eyepiece set directly to you. And we'll pack your eyepieces in the Meade #771 foam-lined aluminum carrying case, itself a $49.95 value if purchased separately. For complete details see the HOW TO ORDER box at right.

Designed and manufactured to exacting standards, Meade Series 4000 Super Plössls deliver wide 52° apparent fields (44° for the SP40mm) with all of the resolution, edge-of-field sharpness, and color correction demanded in the most advanced visual applications. All eyepieces are brand-new and factory fresh; each is multi-coated, includes a soft rubber eyeguard, and is individually packed in a thread-on poly container. There are no finer general-purpose eyepieces available.

The Meade #771 aluminum carrying case, included with this special offer, provides rugged, secure storage for your Super Plössl eyepiece set.

This special offer includes the following eyepieces:

SP6.4mm	$79.95
SP9.7mm	79.95
SP12.4mm	79.95
SP15mm	79.95
SP20mm	79.95
SP26mm	(standard equipment)**
SP32mm	99.95
SP40mm	99.95
#771 Aluminum Carrying Case	49.95
Total price if purchased separately:	**$649.60**

***Telescopes qualifying for this special offer include:**

ETX models: ETX-90EC, ETX-105EC, ETX-125EC
LXD55 models: 6" SN-6, 8" SN-8, 10" SN-10, 8" SC-8, 5" AR-5, 6" AR-6, 6" SN-6EC, 8" SN-8EC, 5" AR-5EC
LX90, LX200GPS models: 8" LX90; 7", 8", 10", 12", 14", 16" LX200GPS

HOW TO ORDER

1. Buy any qualifying Meade telescope from an authorized Meade dealer in the U.S.A. between August 15, 2002 and October 31, 2002.

2. Fax or mail a copy of your dealer's invoice, plus the completed warranty card packed with the telescope, along with your payment of $99 to Meade Instruments/Attn: Customer Service, and request the "$99 Eyepiece Offer." *Requests must include your complete shipping address and phone number.*

3. We will ship your eyepiece package to you within 30 days of our receipt of your request. Meade Instruments will pay for all shipping and insurance charges; safe arrival is guaranteed.

Other terms and conditions: Payment may be made by personal check (payable to Meade Instruments) or credit card (VISA or MasterCard). **California residents must add $7.67 sales tax, for a total payment of $106.67.** Requests for this special offer must be postmarked not later than November 30, 2002. This special offer is valid only for new Meade telescopes ordered and received within the U.S.A. (Outside the U.S.A. contact your Meade international distributor.) There is no limit to the quantity of telescopes each person may order: each qualifying telescope is eligible to receive the special eyepiece package. Prices shown are suggested U.S. mail-order retail prices. **The SP26mm eyepiece (shown in photos above) is packed with each qualifying telescope as standard equipment.

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ETX-125EC
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ETX-90EC
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ETX-105EC
$695
8" SC-8
$1195
6" SN-6
$695
New 14"
LX200GPS!
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14"
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8" SN-8
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Whatever your observing level or budget, there's a Meade telescope that's right for you. And, whatever Meade telescope model you choose, you'll know that you have purchased the finest telescope in its class, optically, mechanically, and electronically. After all, we didn't become Number One in the world without good reason.

ETX-Series: Meade ETX Maksutov-Cassegrains revolutionized amateur astronomy when they were introduced in 1999. Exquisite diffraction-limited imaging with Autostar capability in an ultraportable package.

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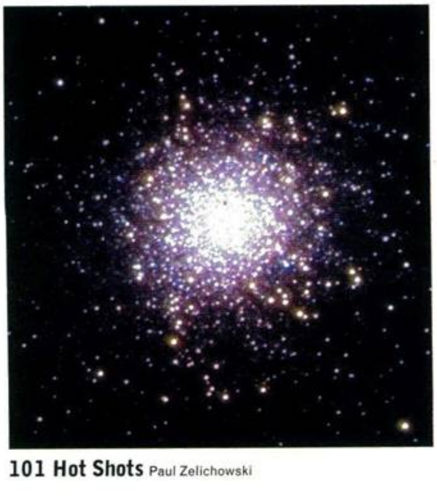

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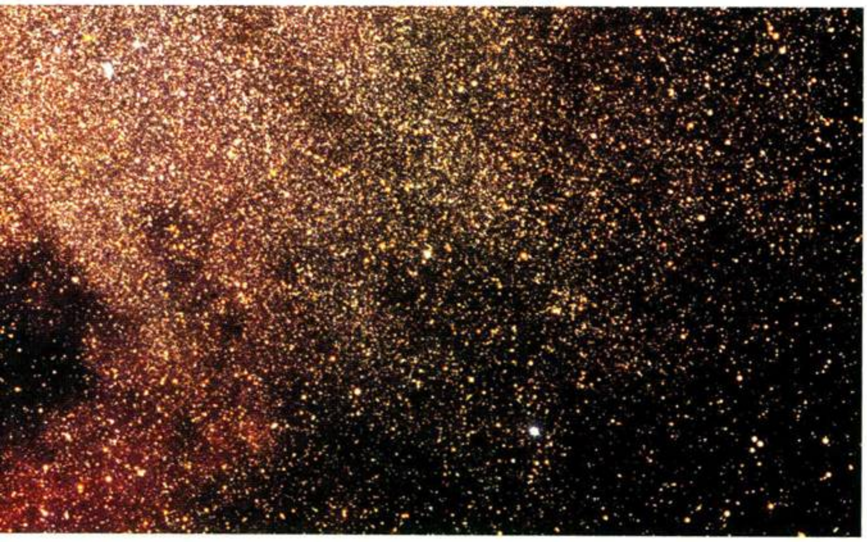

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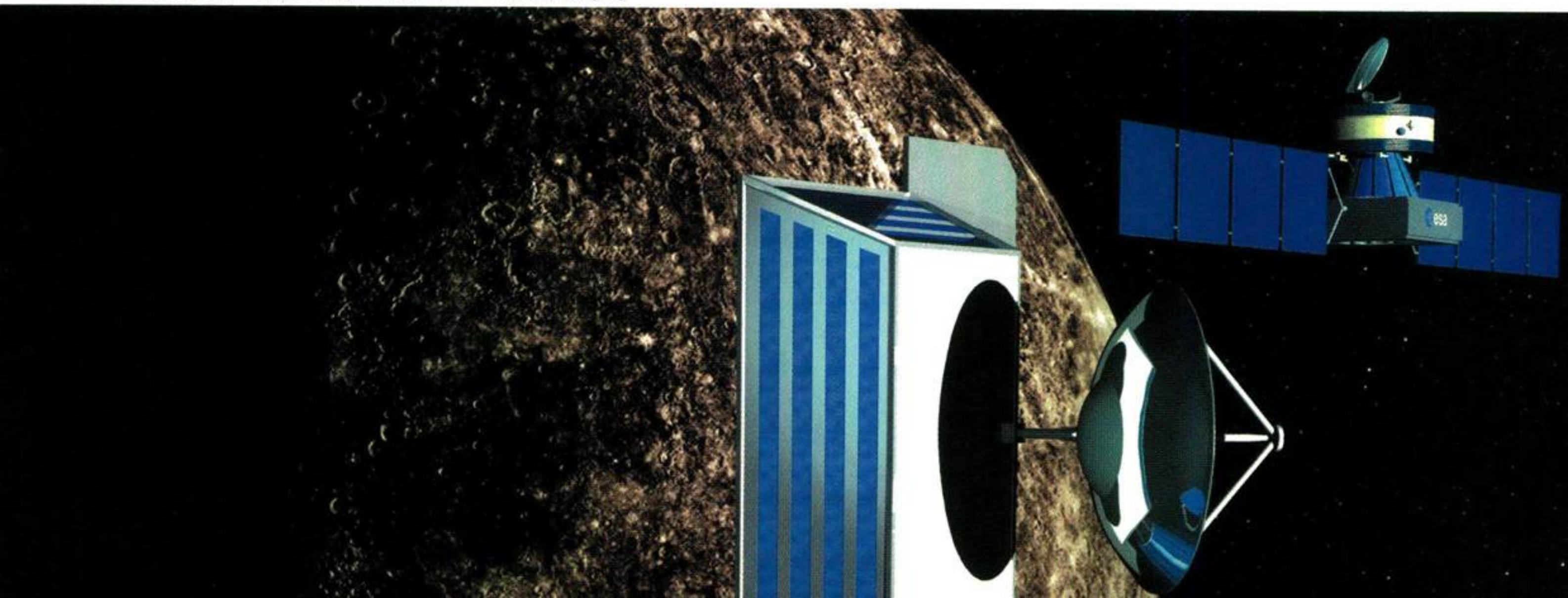

BEHIND THE SCENES

BY DAVID J. EICHER

New Directions

In June Bonnie Gordon, editor of *Astronomy* for the past six years, left the magazine to pursue other opportunities. I'm pleased to announce that Dave Eicher, former managing editor, is the magazine's new editor. He has been working on the magazine for 20 years, having joined the staff in 1982. Dave's involvement with astronomy as a subject goes back to 1976, when as a 15-year-old he went to a star party in his native Oxford, Ohio, and fell in love with observing after seeing Saturn. Subsequently, strongly interested in galaxies, clusters, and nebulae, he founded a little magazine called *Deep Sky Monthly*, which grew in leaps and bounds to a circulation of 1,000 by the time he left Miami University and joined the *Astronomy* staff. *Deep Sky* magazine, commenced in 1982 as a quarterly, was published for 10 years until increasing time commitments on *Astronomy* made it difficult to continue.

Astronomy: Jim Forbes

David J. Eicher

Dave has written seven books on astronomy, including *The Universe from Your Backyard* and *Beginner's Guide to Amateur Astronomy*, and has received several awards for his efforts, including the International Astronomical Union's naming of minor planet 3617 Eicher. When not engaged in astronomy, he has produced seven books on another interest — the American Civil War — the latest being *The Longest Night*. Congratulations, Dave.

James J. Slocum

Jim Slocum
Publisher

I'm thrilled to take the helm as *Astronomy* enters a new era. Over the coming months *Astronomy* will continue to bring you the best articles on what you can see in the sky, the latest astronomical news, the world's most beautiful astronomical imagery, and insights into the hottest areas of astrophysical and cosmological research. We will also be providing more and better articles on a whole array of subjects attached to the hobby of astronomy. My goal is to make this magazine even more exciting, informative, and attractive.

Over the years I have had no greater experience than getting to know the readers of *Astronomy* — meeting you at star parties, astronomical meetings, or through the mail. I invite you to let me know what you like about the magazine and what you would like to see more of. The road ahead should be an exciting one, and I look forward to including you as a participant in what makes this magazine great.

Please join me in welcoming Tom Ford as the new art director of *Astronomy*. A Milwaukee native, Tom is an experienced designer who has worked on not only *Astronomy* but also the Astronomy.com website. Tom counts among his fondest astronomical memories visiting Galileo's house and observatory in Florence, a spot he hopes to return to soon. Please also welcome new associate editor Maggie McKee, who hails from Washington, D.C. Maggie received her B.A. in physics from Grinnell College and is a graduate of the University of California-Santa Cruz science writing program. Tom, Maggie, and the whole staff look forward to the experience of bringing you the best magazine we can over the coming months and years.

Dave Eicher
Editor

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ART DIRECTOR
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Buy a $650 Super Plössl eyepiece set for your ETX telescope for only $99! *See ad in this issue for details!*

"...A prediction: The ETX/Autostar concept will go down as the greatest happening in amateur astronomy yet."

— *Sky & Telescope*, May, 1999

ETX-105EC, shown with optional #497 Autostar controller and T-Adapter.

Since their inception in 1999, Meade ETX telescopes have gone on to become the largest-selling modern telescopes in the world, with hundreds of thousands of ETX's now in the field. And every one with the unique ETX trademarks: matchless optical performance; compact, contemporary design; and revolutionary Autostar GO TO capability. *See the Meade General Catalog for full details.*

MEADE ETX ASTRO TELESCOPES

Complete per catalog specifications:

ETX-70AT with #494 Autostar	**$349**
ETX-90EC with Electronic Controller	**495**
ETX-105EC with Electronic Controller	**695**
ETX-125EC with Electronic Controller	**895**
#497 Autostar controller for ETX-90EC, ETX-105EC, or ETX-125EC	**149**

Ultra-High Transmission Coatings (UHTC) group increases image brightness by about 20% *(see ad in June 2002 issue)*:
ETX-90EC– $50; ETX-105EC– $75;
ETX-125EC– $95

Prices shown are suggested U.S. mail-order retail prices.

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LXD55

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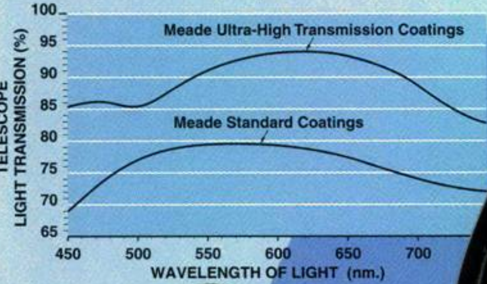
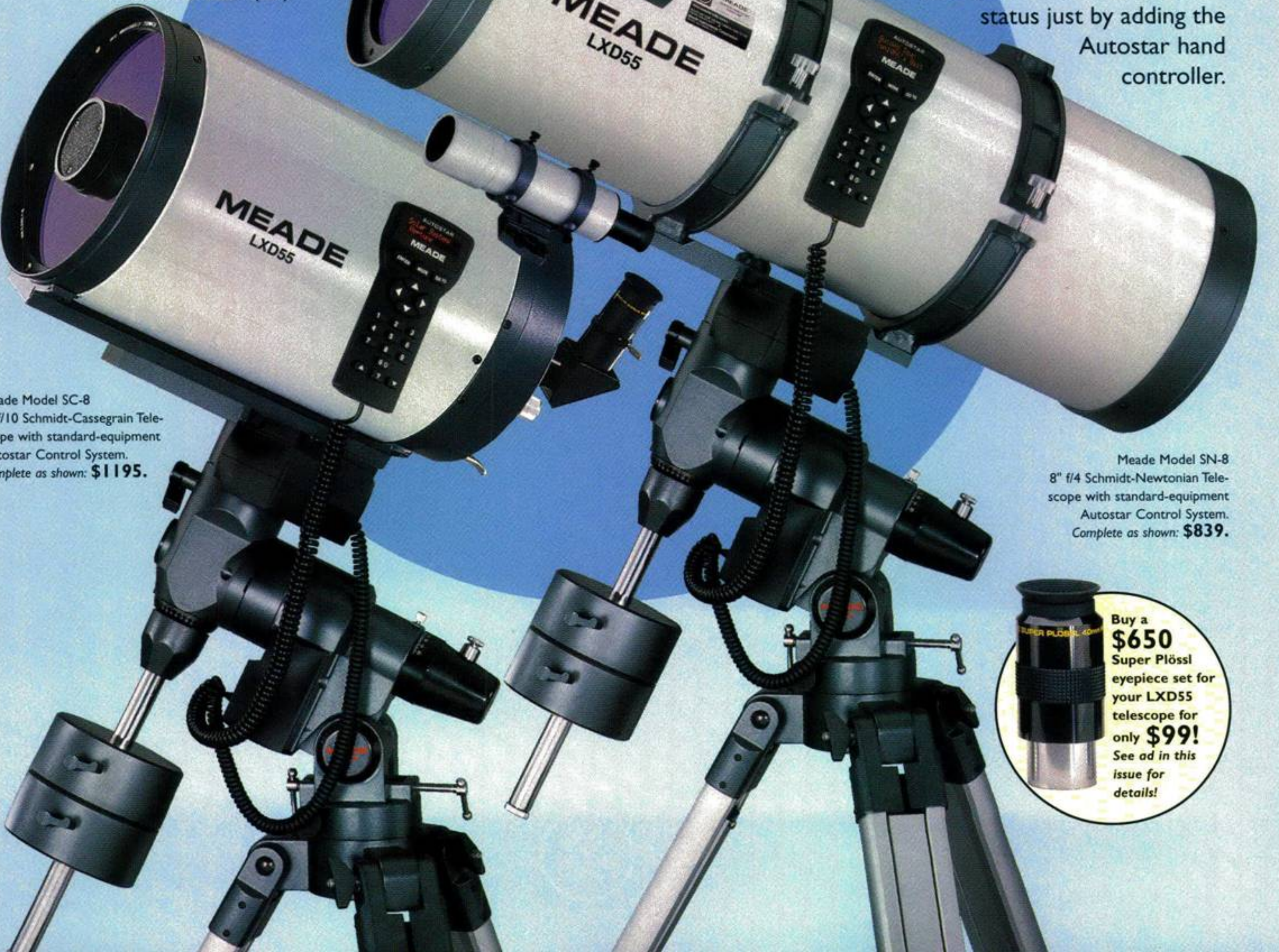
Choose from nine Meade Schmidt-Newtonians, Schmidt-Cassegrain, and Achromatic Refractors, each with Autostar® or Electronic Controller — from $579, *complete!*

Meade Ultra-High Transmission Coatings (UHTC) Group: Available optionally at the time of telescope purchase, the UHTC group increases image brightness by about 20% over the visible spectrum.



Observe ***hundreds*** of galaxies, nebulae, and star clusters of all types ***your very first night out,*** and hundreds more the next night out, simply by pressing the Autostar GO TO pushbutton. Watch as the telescope fast-slews at 4.5°/second, locating each object — from the brightest to the most obscure — and placing it automatically, unerringly, and precisely in the telescopic field. Or choose one of the new EC-models with dual-axis Electronic Controller, telescopes upgradable at any time in the future to full GO TO status just by adding the Autostar hand controller.



Meade Model SC-8
8" f/10 Schmidt-Cassegrain Telescope with standard-equipment Autostar Control System.
Complete as shown: **$1195.**

Meade Model SN-8
8" f/4 Schmidt-Newtonian Telescope with standard-equipment Autostar Control System.
Complete as shown: **$839.**

Buy a $650 Super Plössl eyepiece set for your LXD55 telescope for only $99!
See ad in this issue for details!

6", 8", and 10" LXD55-Series Schmidt-Newtonians with Autostar

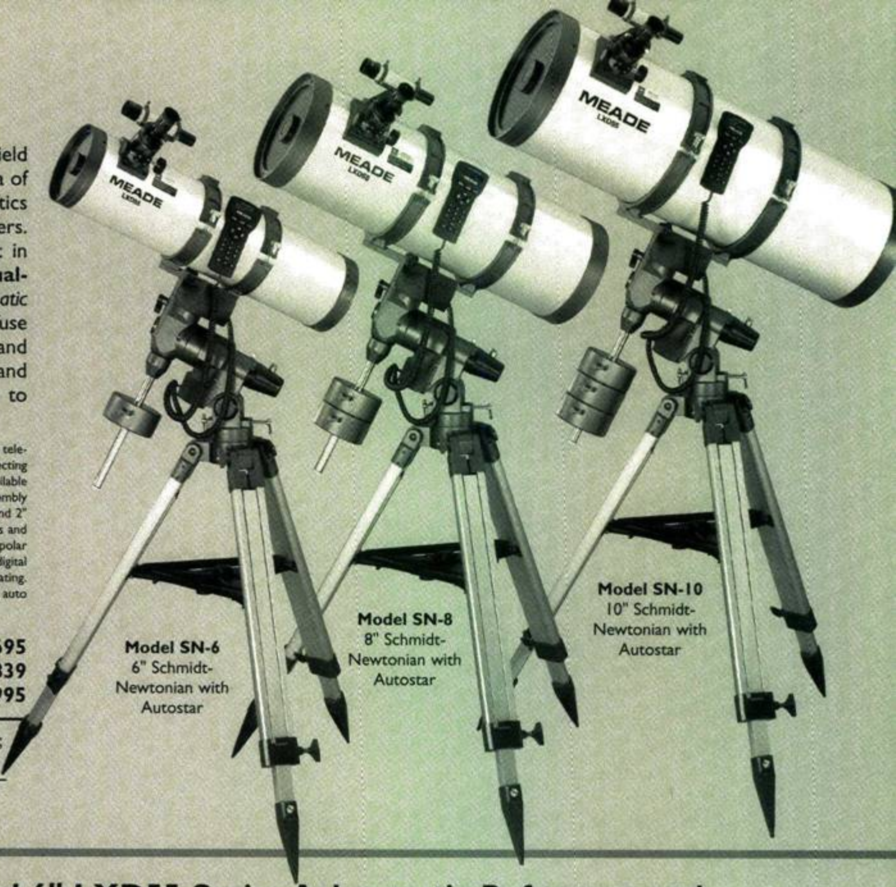
Meade American-made diffraction-limited Schmidt-Newtonian optics yield pinpoint stellar images over extremely wide fields, with *one-half* the coma of paraboloids of the same focal ratios. Fast f/4 (8", 10") or f/5 (6") optics present brilliant, rich-field imaging of nebulae, galaxies, and star clusters. High-power lunar and planetary images reveal subtle detail often lost in telescopes of lesser resolution. The standard-equipment **Autostar Dual-Axis Control System** permits an amazing range of operations: *automatic GO TO capability* at 4.5°/second to 30,223 database objects (galaxies; diffuse and planetary nebulae; star clusters; the complete Messier, Caldwell, IC, and NGC catalogs; double and variable stars; eight major planets; asteroids; and comets); *nine selectable slew and slow-motion speeds* from 1x sidereal to 4.5°/sec.; plus *automatic sidereal-rate tracking* in RA, and much more.

SPECIFICATIONS: Models SN-6, SN-8, and SN-10 Schmidt-Newtonian Telescopes — Each complete telescope includes 6" f/5, 8" f/4, or 10" f/4 Schmidt-Newtonian optical tube assembly with MgF_2 coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors (Ultra-High Transmission Coatings available optionally); white-enameled metal optical tube with machined-aluminum mirror cell; quick-release cradle ring assembly with locks; 6 x 30mm achromatic viewfinder; metal rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces; Series 4000 Super Plössl 26mm eyepiece. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12v DC auto cigarette lighter plug or from 115v AC home outlet); operating instructions.

6" Model SN-6 Schmidt-Newtonian	**$695**
8" Model SN-8 Schmidt-Newtonian	**839**
10" Model SN-10 Schmidt-Newtonian	**995**

Ultra-High Transmission Coatings (UHTC) group: 6" Model SN-6 – $85; 8" Model SN-8 – $125; 10" Model SN-10 – $150.

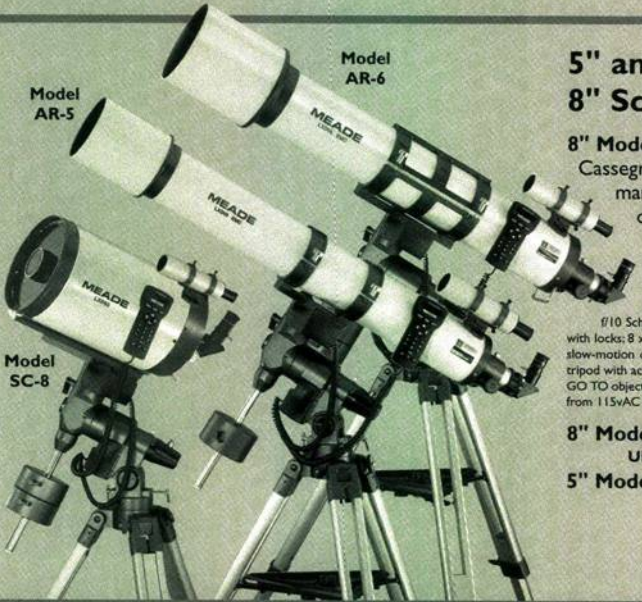
Packing & shipping charges in the 48 states: 6" – $75; 8" – $85; 10" – $95.



Model SN-6
6" Schmidt-Newtonian with Autostar

Model SN-8
8" Schmidt-Newtonian with Autostar

Model SN-10
10" Schmidt-Newtonian with Autostar



Model AR-5

Model AR-6

Model SC-8

5" and 6" LXD55-Series Achromatic Refractors and 8" Schmidt-Cassegrain with Autostar

8" Model SC-8: Includes the f/10 optical system of the Meade 8" LX200GPS for razor-sharp Schmidt-Cassegrain photo-visual imaging of the Moon, planets, and deep-space. All the telescope required by many amateurs for a lifetime of serious observing. **5" Model AR-5, 6" Model AR-6:** Excellent optical performance from the classical 2-element achromat design, with images rich in resolution and contrast and a minimum of chromatic aberration. Models SC-8, AR-5, and AR-6 allow for the full range of Autostar functions described above.

SPECIFICATIONS: Models SC-8 Schmidt-Cassegrain and AR-5 and AR-6 Achromatic Refractors — Each complete telescope includes 8" f/10 Schmidt-Cassegrain with MgF_2/standard coatings or 5" f/9 or 6" f/8 achromatic refractor with EMC super multi-coatings; quick-attach cradle ring assembly with locks; 8 x 50mm viewfinder; Series 4000 Super Plössl 26mm eyepiece; diagonal prism. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); operating instructions.

8" Model SC-8 Schmidt-Cassegrain	**$1195**
UHTC group for Model SC-8	$175
5" Model AR-5 Achromatic Refractor	**695**
6" Model AR-6 Achromatic Refractor	**895**

Packing & shipping charges in the 48 states: 8" – $85; 5" – $85; 6" – $95.

6" and 8" LXD55-Series Schmidt-Newtonians and 5" Achromatic Refractor with Electronic Controller

All the performance and features of the Autostar models above, but with 4-speed (2x, 8x, 32x, 4.5°/sec.) dual-axis Electronic Controller in place of Autostar. Upgrade to the Autostar Controller, available separately, at any time.

SPECIFICATIONS: Models SN-6EC, SN-8EC, and AR-5EC — Identical in every detail to the respective Models SN-6, SN-8, and AR-5, above, but with Electronic Controller (EC) in place of Autostar Hand Controller. Electronic Controller includes four dual-axis slewing speeds: 2x for photoguiding; 8x for image centering in the main telescope; 32x for image centering in the viewfinder; and 4.5°/second for rapid-slew of the telescope across the sky. ***#497 Autostar Controller may be added at any time in the future and, when plugged into the telescope's control panel, permits the full range of Autostar functions, including automatic GO TO, as described for Autostar-equipped telescopes, above.***

6" Model SN-6EC Schmidt-Newtonian	**$579**
8" Model SN-8EC Schmidt-Newtonian	**699**
5" Model AR-5EC Achromatic Refractor	**579**
#497 Autostar Controller, for any EC-model above	**149**

Ultra-High Transmission Coatings (UHTC) group: 6" Model SN-6EC – $85; 8" Model SN-8EC – $125.

Packing & shipping charges in the 48 states: 6" SN-6EC – $75; 8" SN-8EC – $85; 5" AR-5EC – $85. All prices shown in this ad are suggested U.S. national mail-order retail prices.

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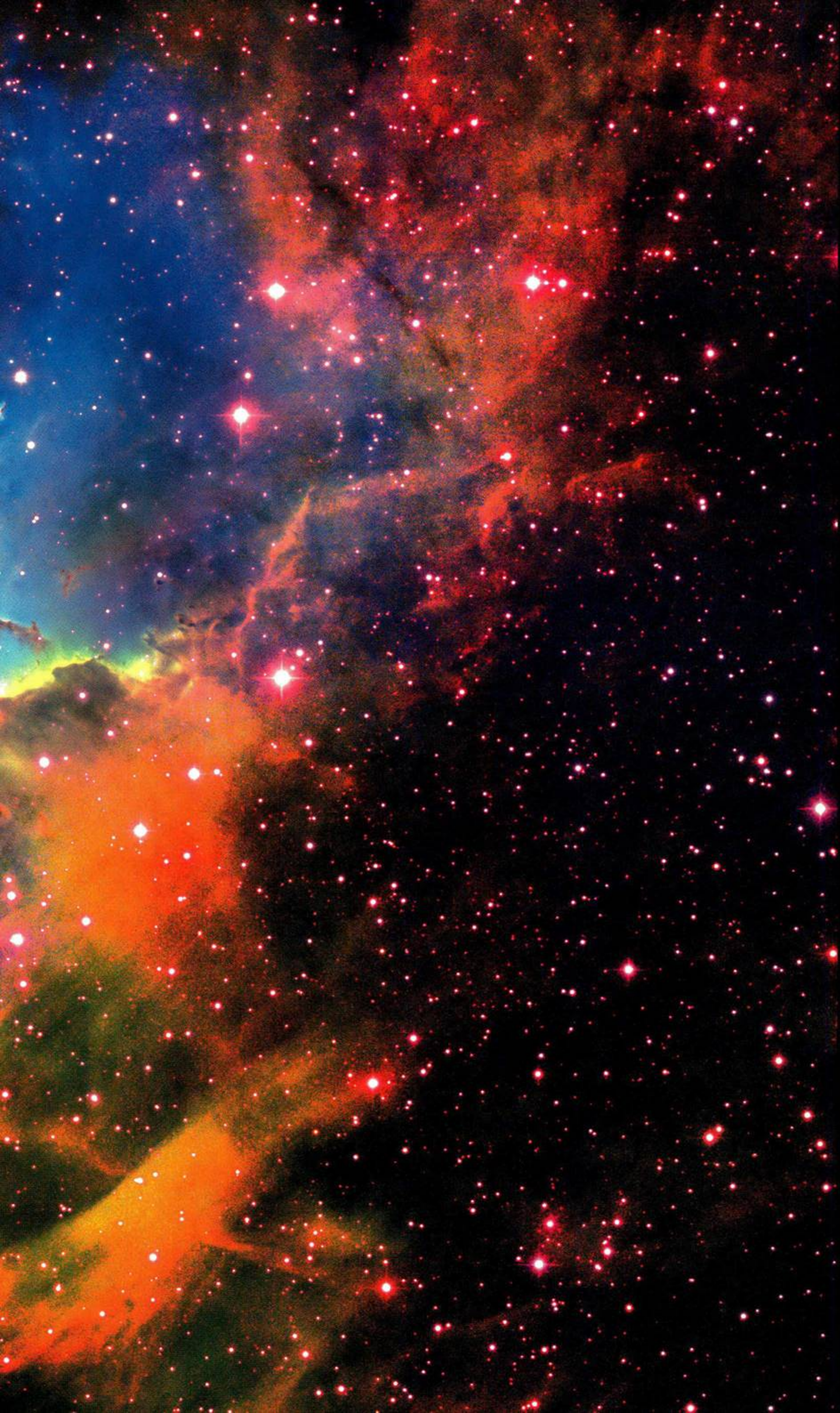
Model SN-6EC
6" Schmidt-Newtonian with Electronic Controller

Model SN-8EC
8" Schmidt-Newtonian with Electronic Controller

Model AR-5EC
5" Achromatic Refractor with Electronic Controller

sky Gem



Let the Eagle Soar

The Eagle Nebula, made famous by a Hubble portrait that zeroed in on the dust pillars at the center of this image, bathes in the glow of the hot, young stars that make up the surrounding open cluster, M16. This image was taken with the 0.9-meter telescope on Kitt Peak in Arizona and the Mosaic camera.

T. A. Rector (NRAO/AUI/NSF and NOAO/AURA/NSF) and B. A. Wolpa (NOAO/AURA/NSF)

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The Best Get Even Better With New Features and Lower Prices

Our popular SkyQuest XT's just got even better with new features such as upgraded Sirius Plössl eyepieces and navigation knobs. Yet they still have the same great performance.

SkyQuest XT4.5
Just the right size for younger stargazers, and incredibly easy to master! Adults will love it too, for its portability and crisp optical performance.

Steel tube, 114mm center marked mirror (f.l. 910mm, f/8), 1.25" aluminum R&P focuser, 5" flanged altitude hubs, CorrecTension Friction Optimization, built in handle, dust cap, Weight: 17.2 lbs. (tube and base). Now With: 6x26 correct-image finder scope, 25mm (36x) and 10mm (91x) Sirius Plössl eyepieces, navigation knob, eyepiece rack, and collimation cap.

$199

SkyQuest XT6
The overachieving XT6 will show Jupiter's Red Spot, Saturn's Cassini Division, hundreds of clusters and nebulas, and galaxies tens of millions of light-years distant. Nicely portable and very affordable

Steel tube, 150mm center marked parabolic mirror (f.l. 1200mm, f/8), 1.25" aluminum R&P focuser, 6x30 achromatic finder scope, eyepiece rack, navigation knob, 5" flanged altitude hubs, CorrecTension Friction Optimization, dust cap, Weight:38 lbs. Now with: 25mm (48x) and 10mm (120x) Sirius Plössl eyepieces (1.25"), navigation knob, and collimation cap.

$349

NOW WITH 2" FOCUSER

SkyQuest XT8
The XT8's prodigious performance on both solar system and deep-sky denizens have made it the telescope of choice for thousands of astronomers, from beginners to die-hard hobbyists.

Steel Tube, 203mm center marked parabolic mirror (f.l. 1200mm, f/5.9), 6x30 achromatic finder scope, eyepiece rack, 5" flanged altitude hubs, CorrecTension Friction Optimization, dust cap, Weight: 43 lbs. Now with: 2" aluminum R&P focuser, 25mm (48x) and 10mm (120x) Sirius Plössl eyepieces (1.25"), navigation knob and collimation cap.

$479

StarMax™ EQ Compact "Mak" Telescopes

The Orion StarMax series brings top-quality Maksutov designs to the amatuer astronomer at an affordable price. All StarMax models feature correct-image finder, EQ mount, and soft-carrying cases for the optical tube.

StarMax 90 EQ
A compact, grab-it-and-go Maksutov-Cassegrain telescope that is a great value for beginners. The StarMax 90 provides a whole new level of versatility, visual clarity, portability and convenience.

A 90mm Mak-Cass design, 1250mm focal length (f/13.9), with 6x20 correct-image finder scope, 25mm Sirius Plössl eyepiece (1.25"), 90° mirror star diagonal, soft carrying case, and sturdy EQ-1 mount.

$279

StarMax 102 EQ
Set-up and break-down takes just minutes with this 4" Maksutov. Transportation is a breeze and its long focal length rewards the viewer with excellent planetary views, such as the Cassini divison of Saturn's ring or Jupiter's red spot. All of this at a very affordable price!

A 102mm Maksutov-Cassegrain design, 1300mm focal length (f/12.7), 6x26 correct-image finder scope, 25mm Sirius Plössl eyepiece (1.25"), 90° mirror star diagonal, soft carrying case, and EQ-2 mount.

$389

StarMax 127 EQ
For the serious amateur astronomer who values performance and quality optics, but also wants portability and easy set-up, the StarMax 127 EQ is just the ticket.

A 127mm Maksutov-Cassegrain design, 1540mm focal length (f/12.1), 6x26 correct-image finder scope, 25mm Sirius Plössl eyepiece (1.25"), 90° mirror star diagonal, soft carrying case, and a sturdy EQ-3 mount.

$569

Orion SkyQuest™ XT10 Dobsonian

Apeture Rules, So meet the New Telescope King

Gulping in over 50% more light than an 8" scope, the XT10 reaches far deeper into space. The sheer number of objects visible in this scope is staggering, and its resolving power brings out detail that will keep you entranced for years.

Steel tube, 250mm parabolic mirror (f.l. 1255mm, f/5), 2" aluminum R&P focuser, big 8x50 achromatic finder scope, 25mm (50x) and 9mm (139x) Plössl eyepieces (1.25"), Moon filter, eyepiece rack, 5" flanged altitude hubs, CorrecTension Friction Optimization, dust cap. Weight: tube 35 lbs., base 23 lbs.

$649

ShortTube™ 80mm Rich-Field Refractor

Suitable for both daytime spotting and casual nighttime stargazing, the ShortTube 80mm can't be beat! Features a fully coated 80mm achromatic objective lens, focal length 400mm (f/5). The white aluminum tube mounts on any camera tripod. Includes a 6x26 correct image finder scope, rack-and-pinion focuser, built-in dew shield, 45° correct-image diagonal, and two 1.25" Kellner eyepieces: 25mm (16x) and 10mm (40x).

$199

SpaceProbe™ 130mm EQ Reflector

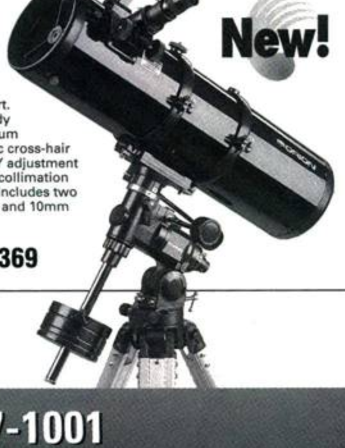
For the novice astronomer, the SpaceProbe provides great all-around viewing performance at an affordable price. One minute you can be studying lunar crater formations at high power: the next, the ethereal glow of a nebular star factory. A few minutes later, the ringed visage of Saturn. All served up in crisp detail by the 130mm (5.1") primary mirror (900mm focal length, f/6.9). The tube assembly rides on the sturdy EQ-2 equatorial mount, which is outfitted with dual slow-motion controls, a beefy hardwood tripod, and accessory tray. Accessories include two fully coated Explorer II eyepieces: a 25mm (36x) and 10mm (90x) and a 6x30 achromatic finder scope. Weighs 32 lbs.

$229

AstroView™ 6 EQ Reflector

A 6"-class equatorial reflector that delivers all-around performance at a great price, with 150mm-diameter parabolic Newtonian optics (focal length 750mm, f/5), an aluminum 1.25" rack-and-pinion focuser, and a four-vane, adjustable secondary mirror support. AstroView 6 is mounted in the sturdy EQ-3 equatorial mount with aluminum tripod. Comes with 6x30 achromatic cross-hair finder scope with spring-loaded X-Y adjustment and quick-release dovetail bracket, collimation thumbscrews and collimation cap. Includes two 1.25" Plössl eyepieces: 25mm (30x) and 10mm (75x). Weighs 39 lbs.

$369



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20x80 WA	3.5° field	**$489**
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Compact astro binocs that show you the light! Fully multi-coated optics, BAK-4 prisms. Long eye relief (8x56: 18mm, 9x63: 26mm,12x63: 17.5mm, 15x63: 19mm). Easily hand-holdable, but also tripod adaptable.

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8-20x50 Venture™ Zoom Binoculars

Finally, an astronomy binocular with continuously variable magnification—from 8x to a whopping 20x!

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EYEPIECES & ACCESSORIES

Epic™ ED-2 Eyepieces

Our new ED-2 eyepieces are made of "Extra-low Dispersion" optical glass that boasts superior refractive properties. Epic 1.25" eyepieces feature a six-element lens design in which two of the elements are crafted from ED glass. Each provides luxurious 20mm eye relief, reduced chromatic aberration and a wide 55° apparent field.

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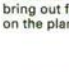

Orion Moon Filter

Cut lunar glare to reveal much more surface detail

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Explorer II™ Zoom Eyepiece

Now even the casual telescope user can enjoy the benefits of zoom eyepiece technology. A twist of the Explorer II Zoom housing changes the focal length from 21mm to 7mm, or any focal length in between. Four-lens eyepiece boasts fully coated optics and long eye relief from 33mm to 16mm. 1.25"

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Our right-angle finder scopes let you view in contortion free comfort! What's more, they have built-in Amici prisms to provide a correctly-oriented, not upside down, view. Available in two sizes. Each comes with dovetail bracket.

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New!

EZ Finder™ II Reflex Sight

We've upgraded our EZ Finder with a new design and improved bracket—at a lower price. This aiming device superimposes a LED-powered red dot in a wide 10° field of view, showing exactly where the telescope is pointed. Now with a new bracket that fits the quick-release mounting base on many Orion telescopes.

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1.25"

6.3mm, 7.5mm, 10mm, 12.5mm, 17mm, 20mm, 26mm	**$49.95 each**
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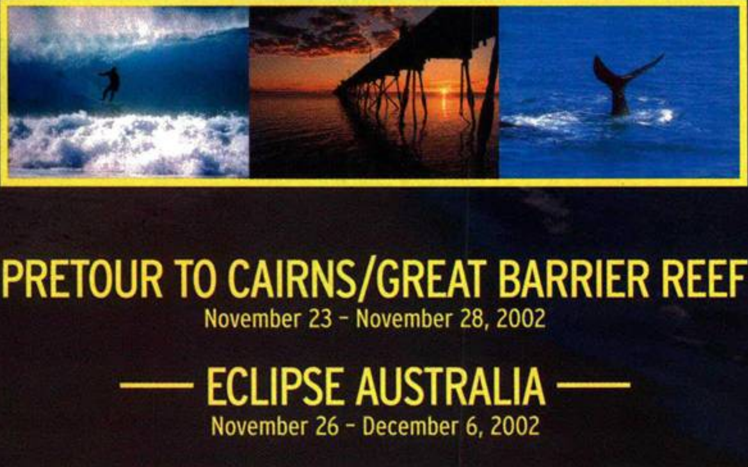

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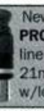

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Mysterious Sightings

I read *Astronomy* cover to cover every month, and I really enjoyed "Close Encounters with Satellites" in the July issue. However, I saw a point that might need to be clarified for those who are not familiar with orbital mechanics.

On page 73, the author discusses the effects of propellant dumps on the orbits of a vehicle and states, "Objects moving backward from the shuttle are then going too slowly to maintain their original altitude, so they slip into lower orbits. By momentum conservation laws, they pick up speed along these new paths and quickly pull ahead of the shuttle, staying slightly below it."

While the author is technically correct, readers should be informed that two speeds are involved. First, the object moving backward reduces its tangential velocity (parallel to Earth's surface below); second, the object that drops into a lower orbit increases its angular velocity (the angular rate of movement of a line drawn from the object to the Earth's center) in order to conserve angular momentum. This explains how an object loses energy by reducing its tangential velocity and yet can pass an object in a higher orbit. — *Tim Brown, Honea Path, South Carolina*

I read "Close Encounters With Satellites" with interest, as it reminded me of my own experience. It was a rainy Friday night in mid-May 1986, and I was a college student studying astronomy. At about 3 A.M. I decided to take a break from my studies to go outside and get a breath of fresh air. As I got to the front door, I noticed an intense patch of red in the sky. It grew brighter and began flickering, as if fireworks were going off just below the horizon. Within seconds, the flickering turned into three balls of light: one blue, one yellow, and one green. Each one was about the size of the full moon. They formed a triangle, each flashing wildly. Soon they faded away, along with the patch of red. I was feeling "brave" at this point, and actually went outside. But no sooner did I step outside the door than the colors in the sky returned. I noticed then that they were so bright that they were reflecting in a puddle of water on the ground. At this point my bravery vanished — I retreated into the house and slammed the door. I was sure that it was a UFO. The next day, I called the Buhl Planetarium and the weather bureau at the Pittsburgh Airport, but everyone I talked to seemed to think I was crazy.

Rocket launches can result in beautiful vapor trails, like this one from Vandenberg Air Force Base in California. Chris Cook

The following week, I told a professor, and she said I must have been looking at Venus. But I knew that was not the case. Two weeks after the incident, I heard that UFOs had been spotted over South America, which sounded very similar to what I had seen. This only fueled my suspicions.

Finally, about five years ago, I heard about a local UFO group, and I wrote to the director. To my surprise, instead of laughing at me, he sent me a newspaper article that described what I had seen. On the night of my "UFO" sighting, NASA had launched two rockets from the Goddard Space Flight Center. One carried a payload of barium, which was to be detonated, and the other carried strontium. The description of what it would look like matched exactly what I had seen. My UFO theory turned out to be false, but instead it turned out to be the coolest satellite experience I have ever had. — *Sherry O'Neill, Pittsburgh, Pennsylvania*

Beginner's Luck

As a beginning amateur astronomer, I really enjoy Jerry Burstein's "Beginner's Sky" column. I am an eighth-grader and the scientific terminology in the magazine sometimes confuses me. But Beginner's Sky is easy to follow, as well as well-written and informative. I also enjoy the beautiful photos that accompany the article every month. Keep up the great work! — *Kathryn Neugent, San Luis Obispo, California*

Correction

On page 75 of the August 2002 issue, the "Perseids shower" photo was mistakenly credited to H. J. P. Arnold. The photo was taken by Jimmy Westlake.

Astronomy invites you to talk back. Send letters to Astronomy *Talking Back, P.O. Box 1612, Waukesha, WI 53187; e-mail to talking@astronomy.com. Letters may be edited for space and clarity. Please include your city, state, and country with all correspondence. If you want to talk back to us, please visit our website, http://www.astronomy.com.*

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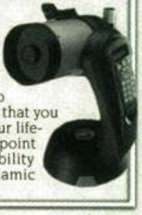

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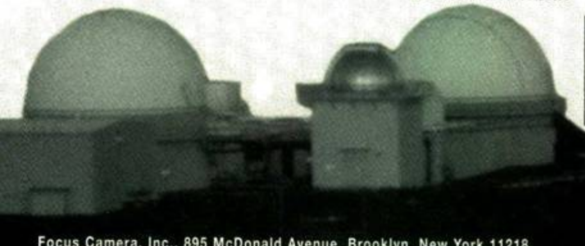

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BLACK HOLES

Distant Galaxies Had Wild Youth

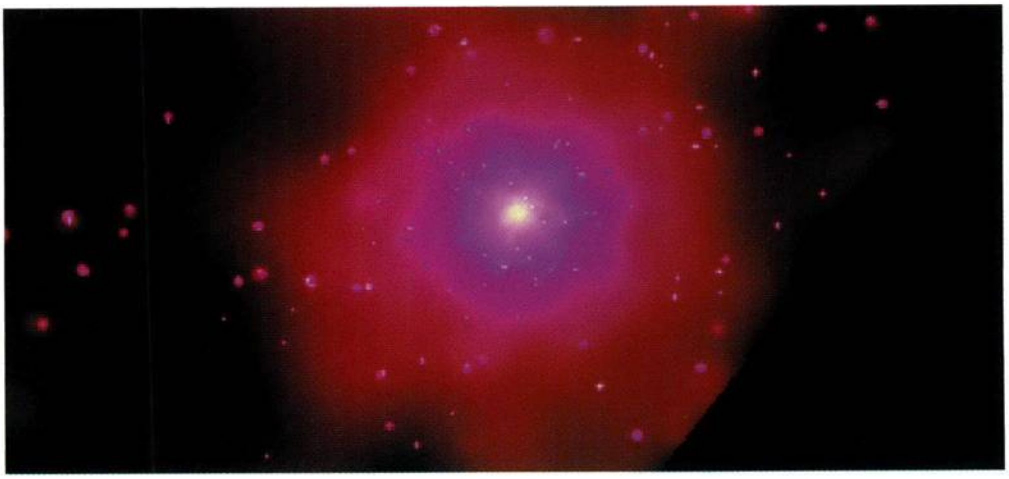
▶ Finding a polyester suit or pair of bell-bottom pants lurking in the back of your closet is a sure way to bring flashbacks of a boisterous youth. Now the Chandra X-ray Observatory has found the galactic equivalent to these retro-styles — huge numbers of neutron stars and black holes prowling the confines of aged elliptical galaxies.

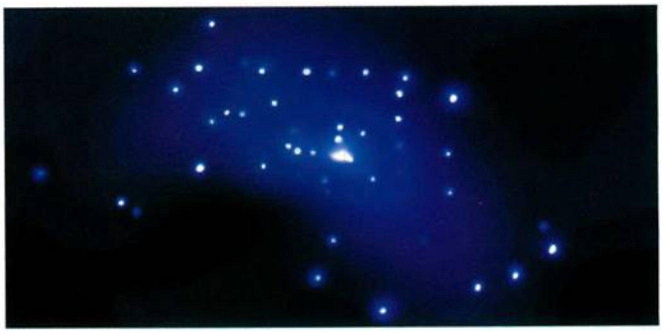
"The black holes and neutron stars we now see in these elliptical galaxies are reminders of their very active past," says Craig Sarazin of the University of Virginia. Sarazin led a team of astronomers who targeted three distant elliptical galaxies: NGC 1553 in the southern constellation Dorado and M60 and NGC 4697 in Virgo. Sarazin presented the team's findings at the June meeting of the American Astronomical Society, held in Albuquerque, New Mexico.

In the present universe, elliptical galaxies are dominated by cool, faint, low-mass stars, most at least 10 billion years old. Yet black holes and neutron stars have no relation to these ancient relics. Astronomers know that black holes and neutron stars are stellar corpses, the remnants of hot, bright, high-mass stars that long ago exploded as supernovae.

Any normal star that contains more than about 8 to 12 times the mass of the sun will eventually end its life as a supernova. Once the star exhausts its nuclear fuel, the pressure generated from within can no longer balance the unrelenting pull of gravity. The star collapses and, in a complex series of lightning-quick events, it detonates, blowing off the star's outer layers and seeding the galaxy with heavy elements.

If the remaining stellar cinder has less than about twice the sun's mass, it ends up as a neutron star, an object with a radius no bigger than that of a large city. If it has more than that, gravity finishes the job. It crushes the remnant into a black hole, a region of space-time from which even light can't escape. Neither a black hole nor ancient neutron star should be radiating much energy, particularly the high-energy x rays observed by Chandra.





Hundreds of point-like x-ray sources dot the elliptical galaxies M60 (above) and NGC 4697 (right). These sources are black holes and neutron stars in binary systems, most located in globular clusters. Above: NASA/CXC/UVa/S. Randall et al.; right: NASA/CXC/UVa/C. Sarazin et al.

The only way these objects can glow brightly in x rays is if they belong to a binary star system. The strong gravity of the collapsed object can draw in material from its companion, typically a normal star that has just started to evolve toward a red giant. Thanks to the conservation of angular momentum, this incoming gas forms an accretion disk around the black hole or neutron star. Friction among the atoms in the disk heats the gas to millions of degrees, causing it to emit the x rays seen by Chandra.

The Chandra observations also show that most of the binaries reside in globular clusters and are not scattered randomly among the other stars in the observed galaxies. That suggests the black holes and neutron stars either captured single stars roaming the cluster or ripped them away from their original companions. The dense environment of a globular — where up to a million stars may be crammed into a volume that would normally hold only a handful — certainly makes capture much more likely.

"Globular clusters appear to be the 'singles' bars' of the stellar world," says Sarazin, "where a lonely black hole can go to find a companion." — Richard Talcott

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THE RED PLANET

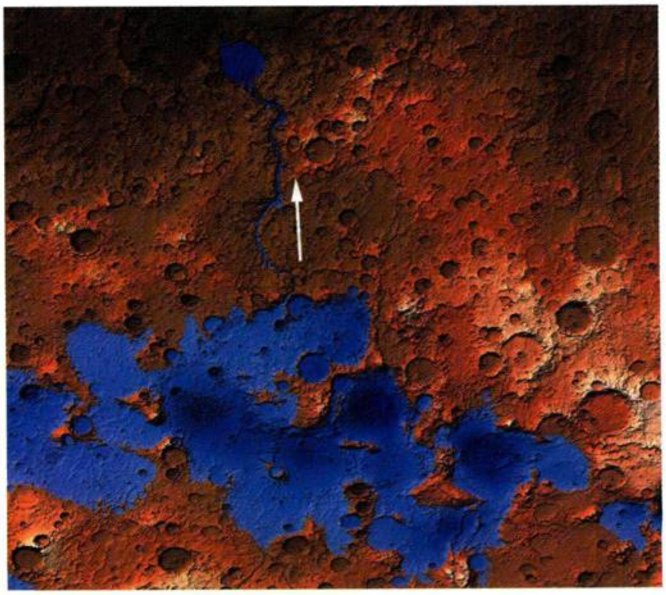
Digging a Grander Canyon

Water spilling from a large, overflowing lake may have created a valley on Mars that's longer and deeper than Earth's Grand Canyon. A team of geologists from the National Air and Space Museum and the University of Virginia report evidence for the former lake in the June 21 issue of *Science*.

After analyzing data from NASA's Mars Global Surveyor, the team found clues that a lake once existed at the head of Ma'adim Vallis. This northward-flowing canyon, which empties into the large crater Gusev in the southern highlands of Mars, is about 560 miles (900 kilometers) long and up to 6,900 feet (2.1 km) deep. For comparison, the Grand Canyon in northern Arizona is 277 miles (446 km) long and 6,000 feet (1.8 km) deep at its greatest depth.

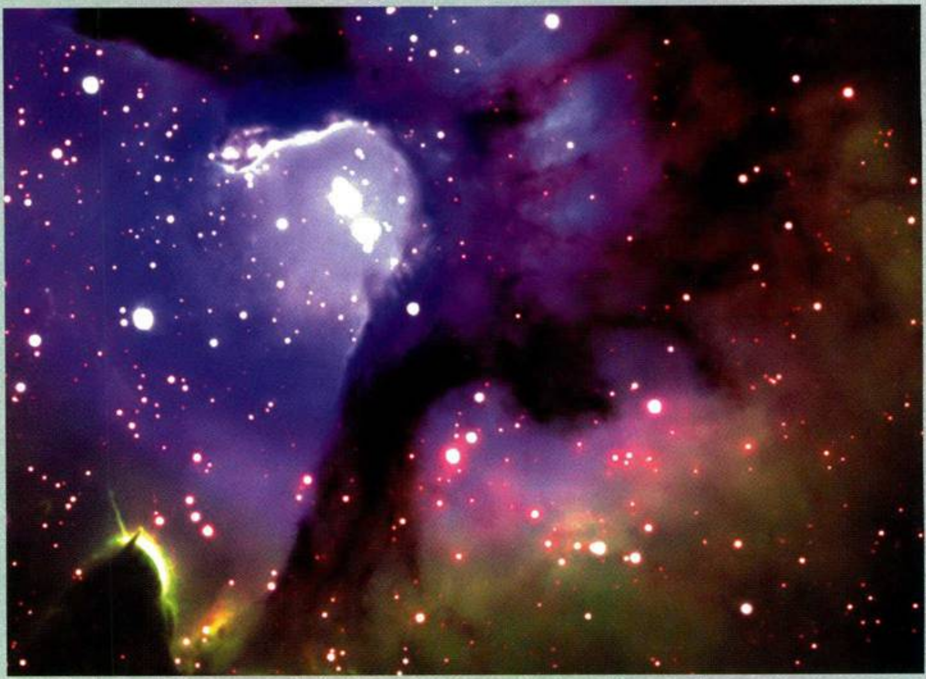
Varying between 5 and 10 miles (8 and 15 km) across, Ma'adim Vallis starts at a ridge, nearly at its full breadth. According to geologist Ross Irwin of the National Air and Space Museum, the most logical explanation for this odd characteristic is that water pooled behind the ridge and eventually spilled over. Irwin heads a group that studied elevation data from Global Surveyor's laser altimeter to look for additional evidence that water may have filled this area.

The team noticed that wide and deep basins within the proposed lake floor don't have the steep walls and flat floors typical of martian impact craters. Instead, their floors are rounded, suggesting water reshaped them by depositing sediment. Above 3,600 feet (1,100 meters), however, the slopes appear steeper and probably weren't so affected. The elevation of this suspected shoreline lies above the height of the ridge where Ma'adim Vallis breaks out



A false-color topographic map of Mars shows a vast lake that may have existed 3.6 billion years ago. When the lake overflowed, it created the northward-flowing (arrow) Ma'adim Vallis. R. P. Irwin III and G. A. Franz, NASM, Smithsonian Institution

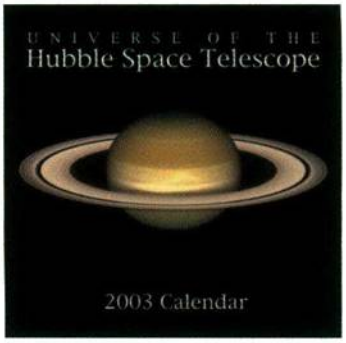
GEMINI TELESCOPE



Gemini Observatory/GMOS image

THREE DUST LANES MEET at the center of the Trifid Nebula (M20), a region of star birth in Sagittarius. The brightest stars at the nebula's center were born about 100,000 years ago, a mere blink-of-an-eye in a typical star's life. The greenish line protruding from the dark finger at lower left is a Herbig-Haro jet, a high-velocity stream of gas typically expelled by very young stars. This jet measures nearly a light-year long, but the nascent star itself lies buried within the dust cloud. The image was made with the 8-meter Gemini North Telescope located on Mauna Kea. It started when 13-year-old Ingrid Braul of Vancouver, British Columbia, won an essay contest in which she proposed taking the Trifid's picture. When the time came, Kathy Roth, the astronomer in charge, decided to shoot a more-detailed image. That, combined with a software bug that yielded twice as much data as expected, led to the deep, rich image.

Introducing Astrographics' Skywatching Guide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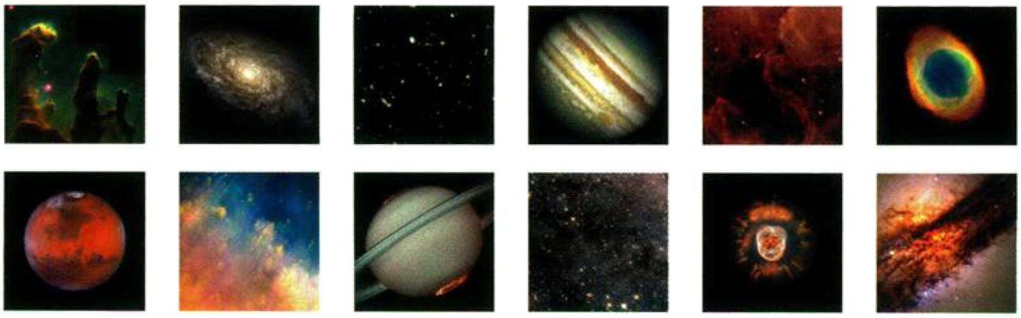

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of the supposed lake. This breakout point also happens to be the lowest level along the lake's perimeter.

The lake would have covered an area of 425,000 square miles (1.1 million square km). When full, it would have contained enough water to cover Texas and New Mexico. "Imagine more than five times the volume of water in the Great Lakes being released in a single flood, and you'll have a sense of the scale of this event," says Irwin.

According to Robert Craddock, Irwin's colleague at the museum's Center for Earth and Planetary Studies, the huge size of the lake suggests that about 3.6 billion years ago, the Red Planet was warmer and wetter than scientists once thought. — VANESSA THOMAS

CONTOUR MISSION

Heading Toward Comet Encke

▶ NASA's bold plan to explore the most primitive objects in the solar system received a big boost on the morning of July 3, when the CONTOUR spacecraft lifted off from Cape Canaveral. CONTOUR — short for Comet Nucleus Tour — will target comets Encke and Schwassmann-Wachmann 3 for close flybys during its four-year mission.

CONTOUR's suite of four instruments will take high-resolution images and analyze chemical composition as it flies just 60 miles (100 kilometers) above each comet's nucleus. Its main camera will be able to show objects as small as 13 feet (4 meters) across — better than ten times the resolution of Deep Space 1 when it flew past comet Borrelly in September 2001 and Giotto when it encountered comet Halley in 1986. A 10-inch-thick dust shield made of Nextel and Kevlar fabric will protect CONTOUR from the dusty comet environment.

The CONTOUR spacecraft blasts off from Cape Canaveral on July 3, 2002. Its path will take it within 60 miles of the surfaces of both comet Encke and comet Schwassmann-Wachmann 3. NASA

"Comets are the solar system's smallest bodies, but among its biggest mysteries," says Principal Investigator Joseph Veverka of Cornell University. "We believe they hold the most primitive materials in the solar system and that they played a role in shaping some of the planets, but we really have more ideas about comets than facts. CONTOUR will change that by coming closer to a comet nucleus than any spacecraft ever has and gathering detailed, comparative data on these dynamic objects."

After spending some 40 days in a highly elongated Earth orbit, CONTOUR was expected to fire its onboard rocket on August 15. That 50-second burn will give the probe enough energy to escape Earth and send it on its way.

On November 12, 2003, it will reach Encke. This comet takes just 3.3 years to orbit the sun and has been seen from Earth more than any comet in history. It's an "old" comet that gives off little gas and dust — though more than astronomers would expect for a comet that has passed the sun more than a thousand times.

After the Encke encounter, CONTOUR heads on to comet Schwassmann-Wachmann 3, arriving there on June 19, 2006. This comet was discovered just 70 years ago and recently split into several pieces, exciting planetary scientists who hope to see a fresh, unaltered surface. If the solar system cooperates and sends a new comet hurtling toward the sun along the right path, CONTOUR could be programmed to intercept it as well.

"By studying at least two comets," says Veverka, "we'll be able to assess their diversity and begin to clear up the many mysteries of how comets evolve." And CONTOUR represents just one leg in NASA's three-pronged attack to understand comets. Stardust will fly past comet Wild 2 in January 2004 and return samples to Earth two years later. That's followed by Deep Impact, which will send a probe slamming into comet Tempel 1 in July 2005, blasting a crater that the main spacecraft will then study. — R. T.

ELLIPTICAL GALAXIES

Young Stars in Old Galaxies

▶ Although most people wouldn't consider them to be as attractive as spiral galaxies, elliptical galaxies appeal to astronomers who want to learn about the history of the universe from

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Contrary to expectations, astronomers have found a host of young star clusters in the ancient elliptical galaxy NGC 4365 in Virgo.

ESA, ESO, Markus Kissler-Patig (ESO), and Thomas H. Puzia (University of Munich)

the ancient star clusters within their bounds. Ellipticals rank among the oldest members of the universe, and astronomers had never found signs of youth within these galactic time capsules — until now.

With help from some of the world's best telescopes in space and on the ground, astronomers from Europe and the United States have become the first to find relatively young stars in one very old elliptical galaxy.

Elliptical galaxies characteristically glow with a diffuse, yellow-to-red hue — a sign of age in the cosmos. Because of this trait, astronomers believed stars in elliptical galaxies formed together during one primeval stage of evolution.

NGC 4365, a 12-billion-year-old elliptical galaxy in the Virgo Cluster, was thought to be no different. That is until astronomer Markus Kissler-Patig of the European Southern Observatory and his colleagues used the Hubble Space Telescope and the Very Large Telescope (VLT) in Chile to observe the galaxy. Along with the ancient globular clusters in NGC 4365, Kissler-Patig's team found clusters of stars that were just a few billion years old.

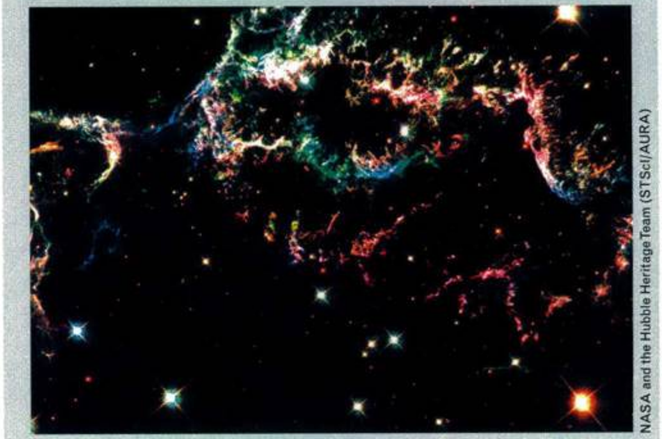
And that's not all. The team actually identified three types of stellar populations in NGC 4365. In addition to the oldest, metal-poor clusters and the newfound young, metal-rich stars, some groupings contained stars that were old but also metal-rich.

The astronomers discovered the younger clusters after combining visible images taken by Hubble with infrared images obtained with the 8.2-meter Antu telescope of the VLT. "We needed the combination of Hubble and the VLT with the latest space- and ground-based astronomical technology to break this new ground," says Kissler-Patig. Follow-up observations with the 10-meter Keck Telescope in Hawaii "fully confirmed" the results, he adds.

This finding shows that elliptical galaxies — or at least NGC 4365 — have experienced additional, more recent periods of star formation since the early days of the universe. It also calls for a change in the way astronomers think about the evolution of galaxies and the history of star formation.

The team reported its discovery at the New Horizons in Globular Cluster Astronomy conference held in Padua, Italy, this June. Their results will be published in an upcoming issue of *Astronomy & Astrophysics*. — V. T.

HUBBLE SPACE TELESCOPE



NASA and the Hubble Heritage Team (STScI/AURA)

THE REMAINS OF A MASSIVE STAR GLOW brightly in this Hubble image of Cassiopeia A. Cas A ranks as the youngest known supernova remnant in the Milky Way Galaxy. About 320 years ago, a star with the mass of 15 to 25 suns blew itself up when it consumed the last of its nuclear fuel. The resulting supernova should have gleamed around magnitude 0, yet no verifiable record exists of such a bright "guest star." Apparently thick layers of dust between us and Cas A, which lies 10,000 light-years from Earth, dimmed the explosion below naked-eye visibility. This WFPC2 image shows the northern rim of the supernova's expanding shell. It reveals thousands of small, gaseous knots rich in heavy elements that are in the process of cooling. A dark blue color represents debris rich in oxygen, while red denotes regions containing lots of sulfur. Eventually, this material will be recycled into future generations of stars and planets.

COMPUTER MODELING

Rocking the Universe

▶ The dynamics and architecture behind supernovae have befuddled scientists for more than 30 years. But now a team of astrophysicists from Los Alamos National Laboratory has tapped into one of the world's fastest computers to construct the first three-dimensional animation of a supernova blast. These life-like simulations should help answer some of the questions that earlier two-dimensional computer models couldn't, say researchers Michael Warren and Chris Fryer, who reported their results at the June meeting of the American Astronomical Society.

Stars destined for a type II finish begin their lives like all other stars — nurtured by the fusion of hydrogen in their cores. But a massive star generates ever-heavier elements until iron fills the core. This marks the end of elemental fusion, and the prelude to one of the most violent deaths the universe has concocted.

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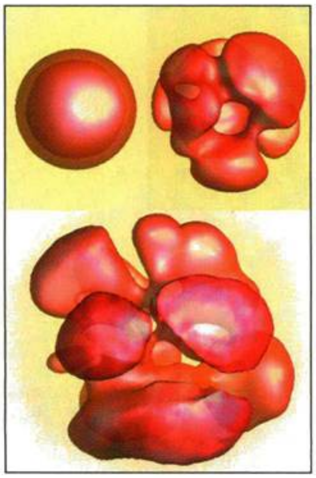


Computer models show 50 milliseconds of a supernova, starting 400 ms after core collapse begins (top left). As gas falls into the core, neutrinos heat it and make it buoyant (top right). As more gas sinks in, it heats up and rises, transferring enough energy to create an explosion (above). Los Alamos National Laboratory, Michael S. Warren

Computer simulations of type II supernovae began more than 35 years ago. These one-dimensional models were plagued by one problem: They failed to explode. Then in the mid-1990s, two-dimensional computer renderings led to a blast. From these simulations, astronomers surmised that convection of gas around the iron core of a collapsing star sparked the explosion. That set the stage for Warren and Fryer's 3-D models, carried out with the IBM RS/6000 SP computer system at the National Energy Research Scientific Computing Center in Oakland, California.

Unable to produce the nuclear-fusion-dependent radiation pressure that traditionally opposes a star's gravitational collapse, the iron-filled core compresses and heats up to billions of degrees. Subsequently, gas in the envelope surrounding the star's core is fired upward in the form of large bubbles, stealing heat away from the core. The more buoyant hot gas gets replaced by colder gas that sinks toward the hot core, where it heats up. The new 3-D simulation shows that this convection transfers enough energy to cause the violent explosion.

Stirling Colgate, a senior fellow at Los Alamos, was one of the researchers who created the first supernova model in 1966. "Our one-dimensional models didn't allow for convection, so they didn't result in robust explosions," he says. "The two-dimensional models demonstrated that convection was important, but we knew turbulence is fundamentally different in two dimensions, so there was still doubt," he adds. "With these three-dimensional results, we have reached the final battleground and are ready to attack the more exotic problems that involve rotation and non-symmetric accretion."

"Modeling the collapse of a massive star represents one of the greatest challenges in computational physics," states Warren. "All four fundamental forces of nature are in play, giving us a cosmic laboratory with conditions unlike anywhere else in the universe. Only if we truly understand the fundamental physics involved and do a perfect job of implementing the computational algorithms will we be able to reproduce the ever-increasing quality of the observational data."

— Paul Morledge

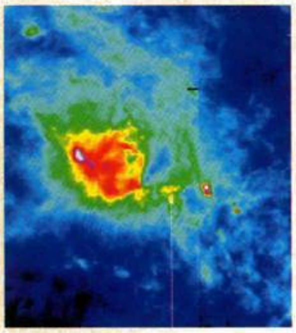
For the latest astronomy news as it breaks, visit us at www.astronomy.com

Light Fights Out of a Black Hole

Einstein's theory of general relativity predicted black holes, and now black holes provide support for general relativity. Relativity predicts that the warped space-time just outside a black hole should affect any light that escapes. Now astronomers have found such an effect. Using the resolution of the Chandra X-ray Observatory with the collecting power of the XMM-Newton satellite, a research team led by T. Jane Turner of NASA's Goddard Space Flight Center examined an iron spectral line coming from the accretion disk surrounding the supermassive black hole in the core of the galaxy NGC 3516. The researchers discovered that the line's width results from gravity stealing energy from the light, as Einstein predicted. "The observation rules out several competing theories attempting to explain the broad iron line," says Turner. "We find that Einstein's predictions ring true."

Rare Molecule Found in Space

A cold, dense molecular cloud in Perseus appears to be the site of some odd chemistry. A team of scientists led by Dariusz Lis of Caltech used the Caltech Submillimeter Observatory on Mauna Kea to find "triply deuterated ammonia" — an exceedingly rare molecule consisting of one nitrogen atom and three deuterium (heavy hydrogen) atoms rather that the single nitrogen atom and three hydrogen atoms in typical ammonia. Although known on Earth, the molecule was thought to be so rare that it would never be detected in space. "From simple statistics alone, the chances of all three hydrogen atoms being replaced by rare deuterium atoms are one in a million billion," says team member Tom Phillips of Caltech. Lis thinks the frigid conditions in the dense cloud — temperatures hover between 10° and 20° above absolute zero — allow the deuterium atoms to settle in the ammonia molecules and stay there.



A dense cloud in Perseus holds an odd molecule. IPAC, Caltech/JPL

A Record-Setting Magnet

A trillion pounds of force would pull a toy magnet into alignment with the magnetic poles of a recently observed pulsar. The object, cataloged as 4U0142+61, belongs to a subset of pulsars known as magnetars for their stupendous magnetic fields. Caltech researchers Brian Kern and Chris Martin used the 200-inch Hale Telescope to study the optical pulses from this object. Combining those observations with x-ray studies yielded the magnetic field's record-breaking strength. It is a quadrillion times more powerful than Earth's magnetic field and 10 billion times stronger than the strongest laboratory magnet ever made.

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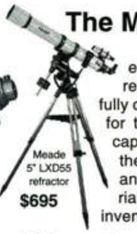

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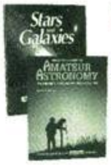

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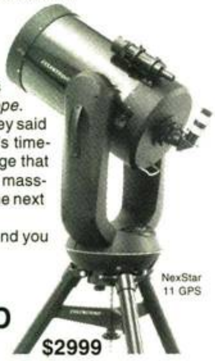
The rave review multicoated *NexStar 11 can* be yours in a week.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Celestron's 11" go-to computerized scope with multicoated optics – the **NexStar 11 GPS** – got a *rave* review in February's *Sky & Telescope.* The review gave it "an enthusiastic two thumbs up and a gold star." They said it has "Brains and good looks. The NexStar 11 GPS puts Celestron's time-tested 11-inch f/10 Schmidt-Cassegrain optics in a sleek new package that includes some of the most advanced electronics ever offered in a mass-produced telescope . . . Celestron is the first to take Go To scopes to the next step in their evolution, and it's a nice step indeed."

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The Stellarvue refractor, "hot new product of 2001."

AT1010A $499⁹⁵
shown w/optional diagonal and eyepiece

The 80mm f/6 **Stellarvue AT1010** achromatic refractor was named a "Hot New Product of 2001" in the December 2001 *Sky & Telescope.* Independent reviews say it competes favorably with ED semi-apos telescopes that cost twice its modest price, and easily outperforms imported achromats in color correction and resolution. The AT1010A has hand-assembled and triple tested optics, tube rings, tripod adapter, 2" focuser with both 1.25" adapter and T-threads, red dot finder, oversize rubberized focus knobs for easier use in cold weather, and a soft padded carry case.

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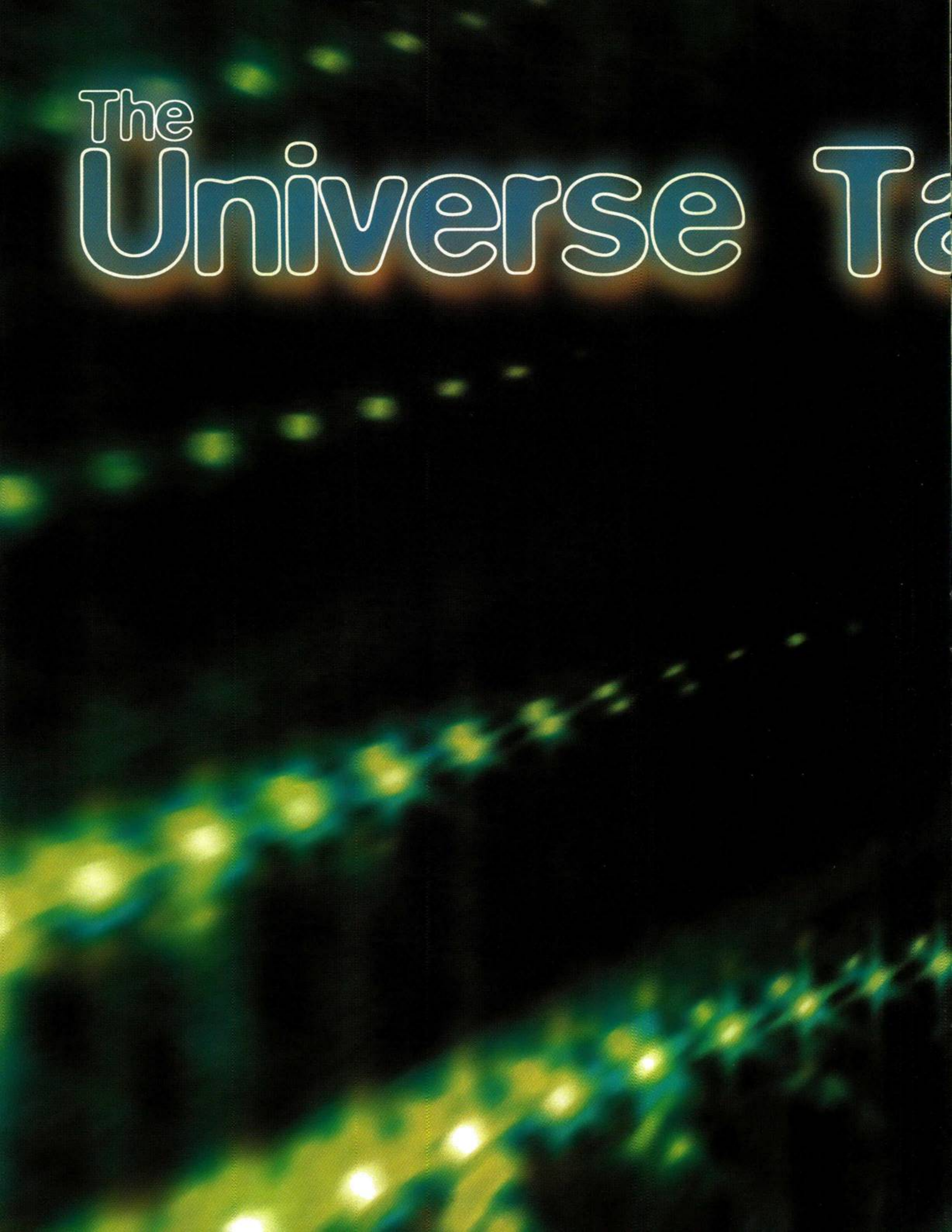
The Universe Ta



akes Shape

Armed with new observational data astronomers are working on an architectural rendering of the cosmos.

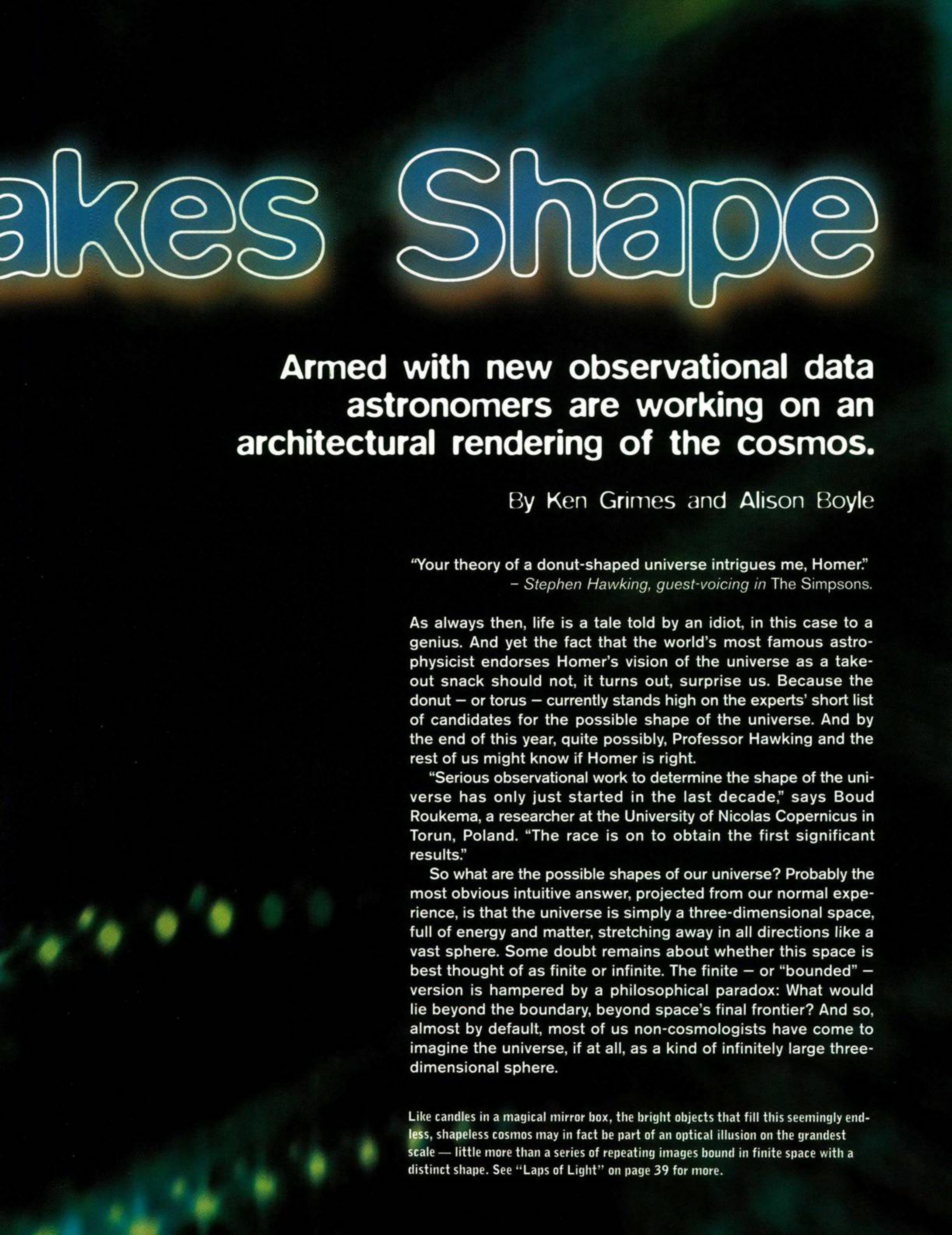
By Ken Grimes and Alison Boyle

> "Your theory of a donut-shaped universe intrigues me, Homer."
> – *Stephen Hawking, guest-voicing in* The Simpsons.

As always then, life is a tale told by an idiot, in this case to a genius. And yet the fact that the world's most famous astrophysicist endorses Homer's vision of the universe as a takeout snack should not, it turns out, surprise us. Because the donut – or torus – currently stands high on the experts' short list of candidates for the possible shape of the universe. And by the end of this year, quite possibly, Professor Hawking and the rest of us might know if Homer is right.

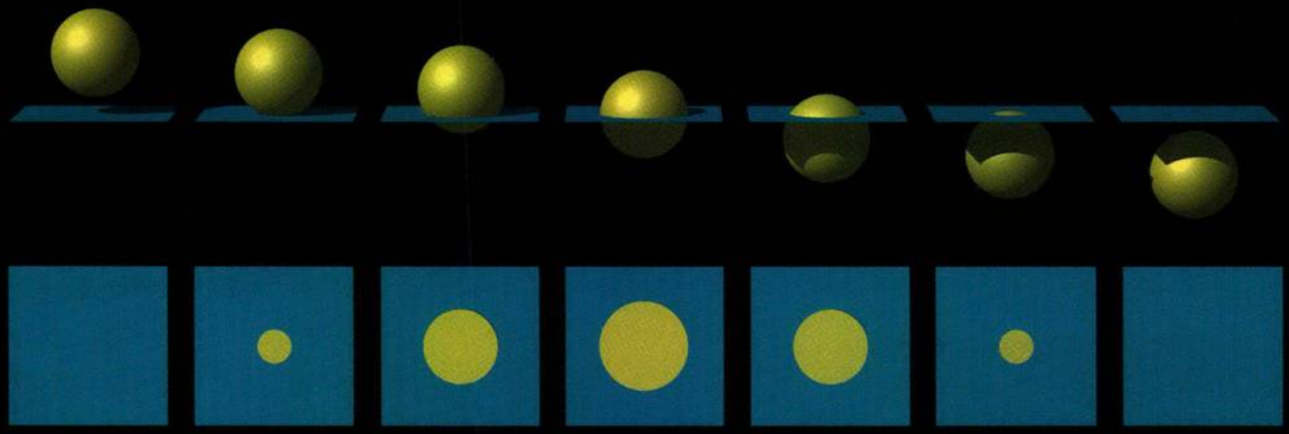
"Serious observational work to determine the shape of the universe has only just started in the last decade," says Boud Roukema, a researcher at the University of Nicolas Copernicus in Torun, Poland. "The race is on to obtain the first significant results."

So what are the possible shapes of our universe? Probably the most obvious intuitive answer, projected from our normal experience, is that the universe is simply a three-dimensional space, full of energy and matter, stretching away in all directions like a vast sphere. Some doubt remains about whether this space is best thought of as finite or infinite. The finite – or "bounded" – version is hampered by a philosophical paradox: What would lie beyond the boundary, beyond space's final frontier? And so, almost by default, most of us non-cosmologists have come to imagine the universe, if at all, as a kind of infinitely large three-dimensional sphere.



Like candles in a magical mirror box, the bright objects that fill this seemingly endless, shapeless cosmos may in fact be part of an optical illusion on the grandest scale — little more than a series of repeating images bound in finite space with a distinct shape. See "Laps of Light" on page 39 for more.

Spacelanders in a four-dimensional world



All illustrations *Astronomy*: Elisabeth Rowan

As far as we can perceive, we who inhabit this universe are creatures of a three-dimensional (3-D) world. However, some cosmologists now theorize that the universe takes on a distinct shape in an imperceptible fourth dimension (4-D), also referred to as "hyperspace."

A higher dimension is difficult to envision, but one way to get a hint of how it might appear as it interacts with a lower dimension is to consider the illustration above. This depicts what a 3-D realm may look like as it passes through the two-dimensional (2-D) world of "flatlanders."

The top row of figures represents how we 3-D "spacelanders" would see a meeting and departure of the two realms, while the bottom row shows how the event might look like to those shallow souls stuck in the flatlands.

This last feature — three physical dimensions — seems, again intuitively, obligatory. The observable universe certainly doesn't have any less than three dimensions, and what could it mean to have more? For mathematicians, at least, the answer to this last question is simple. We can represent any point in three-dimensional space with three coordinates, say x, y and z, where x is the left-right, y the forward-backward, and z the up-down term. By simply adding a fourth term, say w, we can mathematically represent any point in four dimensions.

Such a fourth dimension — also known as hyperspace — would exist at right angles to everything. This fact makes it very difficult, some commentators would say impossible, to picture or imagine a fourth dimension. Attempts to communicate a sense of this extra "axis" of reality are usually made through analogy. Imagine a world of "flat" beings, inhabiting a two-dimensional realm like an infinite tabletop. Such planar creatures and their world would stand in the same relationship to us that we do to a hypothetical fourth dimension.

This hard-to-visualize fourth dimension is particularly intriguing to cosmologists because it can be used to imagine how the universe might be closed. An immediate critique of this idea is that, to the best of our knowledge, the fabric of space certainly doesn't appear to curve toward closure, at least not locally. But, turning to analogy again, imagine you lived on the surface of a sphere. If this sphere were large enough, its curved surface would appear flat — or two-dimensional — in the local vicinity, disguising from its inhabitants the existence of a third dimension "bending" the other two. In fact, of course, you do live on such a sphere — Earth — whose "extra" third dimension remained hidden to its inhabitants for much of their history. A new wave of cosmologists is now proposing the cosmic equivalent of discovering that Earth was a sphere.

From Donuts to Pretzels

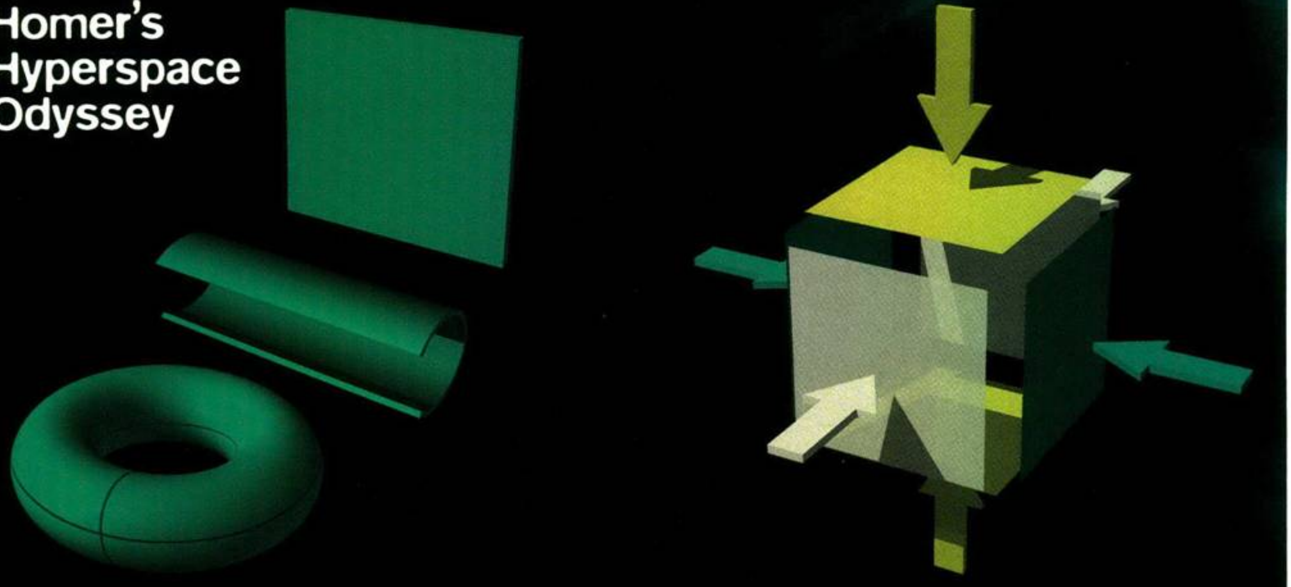
Into what kinds of shapes, then, might the universe be bent in hyperspace? Well, take a square flat sheet of rubber and bend it until two of its opposite edges join, producing a cylinder. Now join the two edges of the cylinder, producing a shape known technically as a "two-torus," the shape of the common donut. The two-torus has a higher-dimensional analog known as a "three-torus." A three-torus could theoretically be made by taking a rubber cube, and bending it in such a way that all three pairs of matching faces — front and back, left and right, top and bottom — were joined to each other simultaneously. If this "cube" were the entire space of our three-dimensional universe, then the bending operation, which can be imagined by recourse to a fourth dimension, would produce the three-torus "donut" of Homer's theory.

Again, this concept is easier to model mathematically than it is to imagine. A computer simulation of a three-torus world simply makes opposite cube faces contiguous with each other. The classic "Asteroids" video game did this in one less dimension: objects leaving the screen at one edge instantly re-appeared at the opposite edge. Now imagine a cubic "Asteroids" screen, where objects passing out through one square face instantly re-enter through the opposite one, and you have managed your own simulation of Homer's three-torus world.

And as Homer would no doubt be comforted to hear, there is more than one way to make a donut. Janna Levin of the University of Cambridge notes, "If we artificially bend a hexagonal tile into three dimensions and glue the sides together, what we find is another way to make a torus."

And why stop with only six faces? An octagon with its eight triangular faces paired (or "glued"), would produce a figure-eight, or double-holed pretzel shape, a promising subject for a future exposition by Homer. The appropriate "Asteroids" screen

Homer's Hyperspace Odyssey



The 4-D shape of a so-called three-torus is best represented mathematically. However, we can concoct its lower-dimensional analog, the donut-like two-torus, which then hints at the making of a three-torus.

Above, left: The making of a "donut," or two-torus, from a square flat piece of rubber.

Above, right: A three-torus is made with a rubber cube, representing the entire 3-D universe. If we could bend the cube in such a way that all three pairs of matched faces were glued together, we'd behold a three-torus.

would be an eight-sided solid, with objects simultaneously entering and leaving the four pairs of opposite "glued" screens.

Beyond the Edge

This cosmic origami generates universes of a definite shape and of a finite size, and yet without the problematic "edge" of earlier models. Again, it helps to think of our analogy in three dimensions. "The surface of our Earth is a definite shape and a finite size," observes Levin. "And yet it does not have that 'edge' that Renaissance explorers feared to sail over." In fact, any journey in a straight line over Earth's surface results in a circumnavigation of the globe, so that all straight-line journeys end where they began. The same would be true for our closed universe. Like an "Asteroids"-type starship, any object voyaging outward from Earth in a continually straight trajectory would eventually return to its point of origin, having traversed the entire circumference of the universe.

The term "any object" includes, of course, particles of light, or photons. In a closed, curved universe, light itself would describe a curved path, eventually returning to its point of origin. Therefore a light source — such as our own galaxy — would project an image of itself which, after traversing the circumference of the universe, would be visible from itself. And the light would not stop there, but would continue traveling; and, if the universe were old enough, the light would eventually circumnavigate the universe once more, projecting a second image back onto its original light-source. And so on for subsequent "light-laps" of the universe.

The implications for contemporary cosmology are truly staggering. When we look up at distant galaxies in the night sky, it is possible that what we are seeing is not a single, vast or infinite number of galaxies, but the same finite set of galaxies repeated throughout the sky, like torchlights in a hall of mirrors. "The universe could appear vast to us, 'unfolded,' filled with billions of galaxies," observes Jean-Pierre Luminet, Director of Research at the Paris Observatory. "It would actually be much smaller, 'folded up,' and contain only a small number of objects. A gigantic optical illusion."

It's All in the Fundamentals

Such an "illusion" would, however, offer the possibility of experimental investigation. If the visible universe is in fact a virtual honeycomb built up from a single building block, or "fundamental polyhedron," then study of the sky could allow us to decide what shape that polyhedron is.

And there are many contenders. In normal three-dimensional space, only the cube or regular hexagon of Homer's donut can be fitted together (or "tiled") to produce a honeycomb. However, it turns out that we don't yet know just how "normal" space actually is.

"Space-time tells matter how to move, and matter tells spacetime how to curve," goes the pithy summary of Einstein's Theory of General Relativity. The amount of matter in the universe determines the curvature of space, which could be flat, spherical or hyperbolic.

A flat universe results from a certain density of matter, known as the critical density. If the density of matter is greater than the critical density, we get spherical curvature, and for densities less than the critical density we get hyperbolic curvature. We don't yet know what the density of the universe is, because much of its content seems to be in the form of dark matter, which we can't see. But current observations suggest that the universe is pretty close to flat, in the same way that any continent on Earth is pretty close to flat.

The geometry of the flat universe is reassuringly similar to what we learned in math classes at school — parallel lines never meet, and the angles of a triangle always add up to 180°. But these rules don't apply for the other universes. In the spherical universe, parallel lines eventually converge, much as lines of longitude meet at Earth's poles, and triangle angles total more than 180°. Whereas in the hyperbolic universe, parallel lines tend to diverge, and the angles of a triangle add up to less than 180°.

The number of contenders for shapes that could tile a flat universe is limited, but a spherical or hyperbolic universe offers endless possibilities. Particular shapes of tiles will only work for specific curvatures. Imagine trying to tile your (flat) floor with octagonal tiles — it can't be done because they overlap. However, if you lived in a hyperbolic house, the octagons would tile the floor perfectly, because the smaller angles they occupy in hyperbolic space mean they can be tiled without overlap. In fact, Homer's octagon-based double-holed pretzel universe would only be possible in hyperbolic space.

Chasing Ghosts in Mirror Worlds

Whatever the eventual shape, there is an obvious method to detect it. As simply put by Roukema, "A single object should be seen in different sky directions and at different distances." The precise pattern of these object repetitions would allow cosmologists to distinguish between the different proposed shapes of the universe.

The natural original candidates for such research were galaxies themselves. The new theorists have been ransacking current sky maps and astronomical data catalogs in the hope of identifying galaxy twins (or perhaps octuplets, depending on the eventual shape) in different parts of the sky. But this project is turning out to be more problematic than the researchers anticipated. The further removed in the virtual honeycomb the "ghost cell" containing a galaxy, the longer its light takes to reach us. This means that the same galaxy viewed in different cells would be at different ages in its evolution. According to Levin, "Trying to match galaxies is like trying to match pictures of babies with pictures of their elderly selves." In addition, images from different ghost cells of the universe would reach us from different angles, requiring matching galaxies to be viewed from different directions as well as at different ages.

Another option is to look at quasars. These are the brightest and most distant objects yet discovered, and so would allow us to look for patterns on larger scales. However, this method suffers from the same problems as galaxy matching. Quasars also look different at different stages in their evolution. And they emit electromagnetic radiation in a non-symmetrical way, again making identification from different angles difficult.

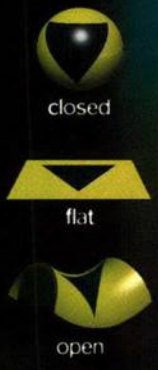
Researchers are still hoping that with more comprehensive data maps, such as the Sloan Digital Sky Survey, and more sophisticated statistical analysis, galaxies and quasars will help to provide a solution. But, at the moment, a different method offers the best bet in the race to determine the shape of the universe.

This method looks back even further in time, to the universe's very first light. We can still detect some leftover radiation from the Big Bang. The Cosmic Microwave Background, as it's known, offers an ideal snapshot in time, according to Neil Cornish of Montana State University.

When we study the microwave background, we are looking back in time as far as we can see, to a wall of light known as the "surface of last scattering." Immediately after the Big Bang, the universe was a seething mass of particles and photons. Photons scattered off matter, much as they would off water droplets in fog, and couldn't go anywhere. It took around 400,000 years

Cosmic Geometry

The amount of matter in the universe determines its density. In turn, the density determines the curvature of space-time, which could be flat, spherical (closed), or hyperbolic (open).



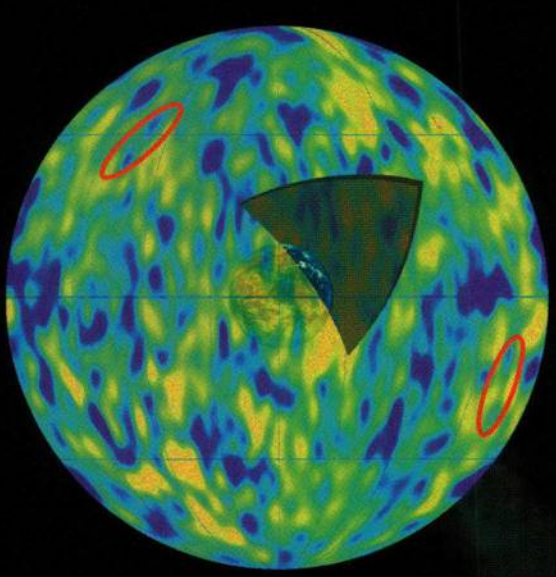
In a closed universe parallel lines always meet and the sum of the angles in a triangle exceeds 180°.

In a flat universe parallel lines never meet and the sum of the angles in a triangle equals 180°.

In an open universe parallel lines tend to converge and the sum of the angles in a triangle is less than 180°.

Current observational data suggest the universe is very near flat, but may teeter toward open or closed.

Microwave Matchgame



Whan astronomers look at the Cosmic Microwave Background (CMB) they are also spying a wall of light known as the "surface of last scattering." This was, in effect, the universe's incipient release of photons, which have traveled the same distance to reach us at the same time (since the speed of light is finite).

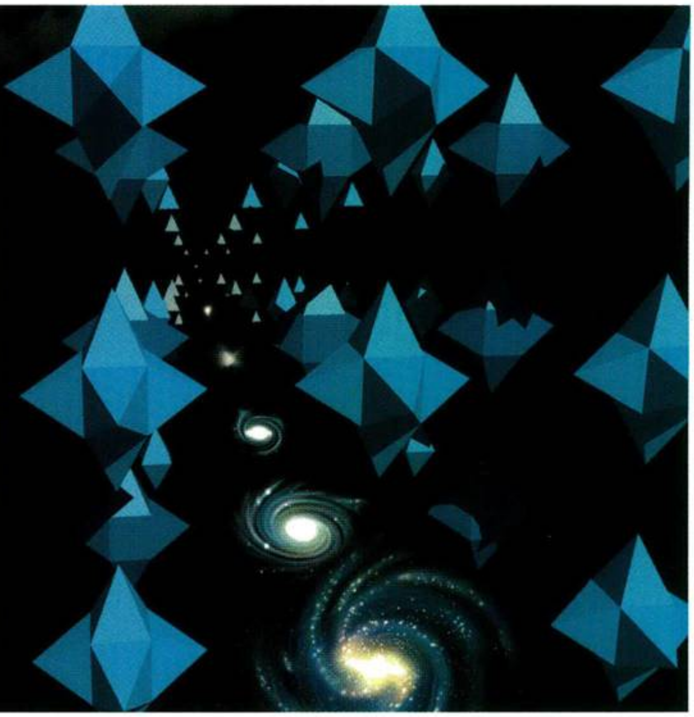
Because of this fact, researchers can examine the inside of this "wall" (shown above as the inside of a sphere surrounding Earth) using COBE and future MAP data to look for matching patterns in CMB temperature fluctuations. If matches are found, then cosmologists will be fairly sure of the universe's curvature and could possibly decipher the shape and size of the "fundamental polyhedron" constituting the universe.

Laps of Light

In a closed, curved universe light would be bound to return to its point of origin. A light source, such as our Milky Way Galaxy, would project an image of itself which, after rounding the universe, would also be visible from itself. If the universe were sufficiently old the light would keep on circulating the cosmos, making a series of "light laps," and observers would see a series of multiple ghost-like images of the same object.

The hypothesis seems easy to test – find objects that are exactly alike and we can be reasonably sure we live in a closed universe. Unfortunately, this experiment would only work if the speed of light were infinite. However, it's finite, of course, which means the farther the object lies from the observer, the younger it will appear. Moreover, celestial objects change over time (as represented here by the pyramids evolving into octahedrons) and may look quite different over billions of years.

The Milky Way Galaxy is shown here in its progression from a diffuse gas cloud to a protogalaxy, and then on to the intricate spiral structure that we see today.



before the universe had cooled sufficiently for the particles to combine to form hydrogen, which photons can pass through.

Anything before the last photon scattering is forever clouded from us, but we can detect the first photons to have escaped. We find them at microwave wavelengths, at a temperature of 3 Kelvins (–454° Fahrenheit, or –270° Celsius). Since they must have all traveled exactly the same distance to reach us at the same time (because the speed of light is finite), we see the wall of last scattering as the inside surface of a sphere, with Earth at its center.

So, if the universe is tiled, and there are many different copies of Earth, there must be many copies of this sphere. If the shape of the fundamental polyhedron is small enough, these spheres will intersect, along circles. The size of these circles would depend on how much the spheres overlapped, and so would give an indication of the size of the fundamental polyhedron.

Is the Writing on the Wall?

But how can we spot these circles? From 1989–93, NASA's Cosmic Background Explorer (COBE) mapped the microwave sky, and found that it's not a perfect 3 Kelvins everywhere — there are slight fluctuations in its temperature. Cornish, along with his collaborators David Spergel of Princeton University and Glenn Starkman of Case Western Reserve University, thinks that searching for patterns in these fluctuations may be the key to finding out the universe's shape.

The team hopes to trace out different temperature patterns along circles, and then find the same pattern along another circle elsewhere in the sky. "Patterns of temperature around one circle should be identical to another," says Cornish. The precise pattern of circles will indicate the fundamental polyhedron's shape.

COBE's achievement in making the first map of the microwave sky was impressive. But the map wasn't quite detailed enough for pattern-spotting. NASA's Microwave Anisotropy Probe (MAP), launched last year, will map the microwave sky in unprecedented detail, providing the data that Cornish, Spergel and Starkman need for their search. "MAP will finish its first complete scan in March and then we can begin our analysis," says Spergel. "We hope to have the results by the end of the year."

Of course, you can draw an infinite number of circles of every possible size on the sky, so they have a gargantuan task ahead of them. It would take months of supercomputing time to sift through all the data. To speed things up, they are first going to look for the signatures of shapes corresponding to flat and spherical curvatures. "This way, if you pick one circle, you know the most probable location of its image," explains Cornish. "Every shape produces a unique fingerprint — if we find it we can pin down the shape of the universe."

If nothing comes out of the search for flat candidates, they will move on to the search for candidates from the infinitely large spherical and hyperbolic families. If nothing comes out of this, it doesn't necessarily imply we live in a simple, non-tiled universe. The universe could still be tiled, but the fundamental polyhedron might be so humongous that its edges are way beyond our view.

"If the universe is relatively large compared to its age, that is, if it's significantly bigger than about 15 billion light-years across," Levin observes, "then light from our ghost images will not have time to reach us before the death of this planet."

The Shape of Things to Come

So the universe may indeed be finite and bounded, and yet too vast to yield to us the secret of its shape. Alternatively, the universe may possess spherical or hyperbolic curvature, and so hide its secret shape among limitless possibilities. Such thoughts are met with quiet stoicism by the new wave of cosmologists: "The universe is however it is," Roukema acknowledges, "not how I would like it to be."

But there remains the tantalizing third possibility — that the universe is actually quite small, and possesses flat curvature. In that case, within a few months of reading this article, we might well know whether Homer's donut is truly the shape of things to come. ◼

Ken Grimes and Alison Boyle are freelance science writers in London.

Heading Back to the Forgotten

Mercury has spent the last 25 years in scientific exile. Now, with two new spacecraft in the works, this little planet steps to center stage.

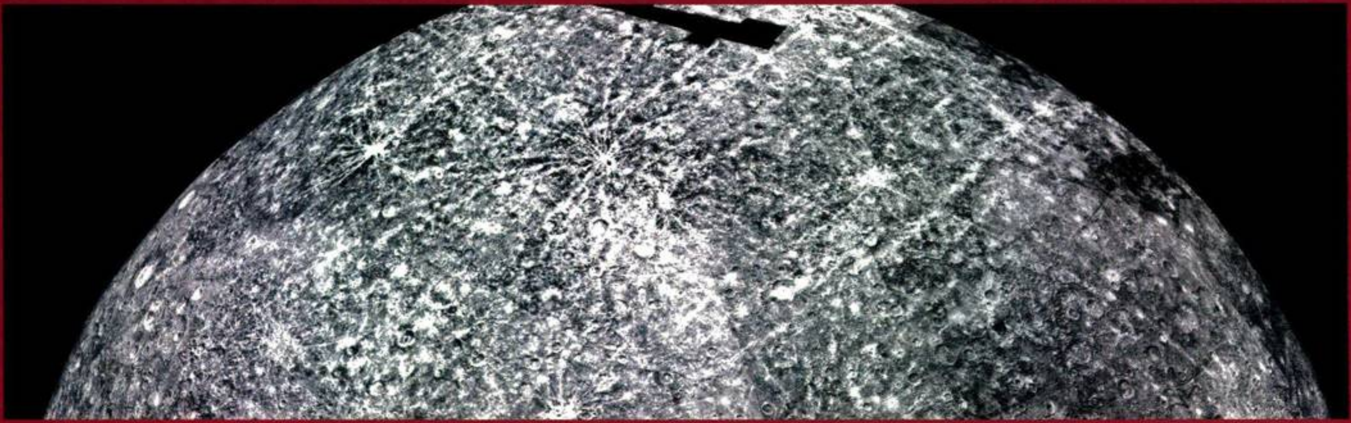
by John Armstrong

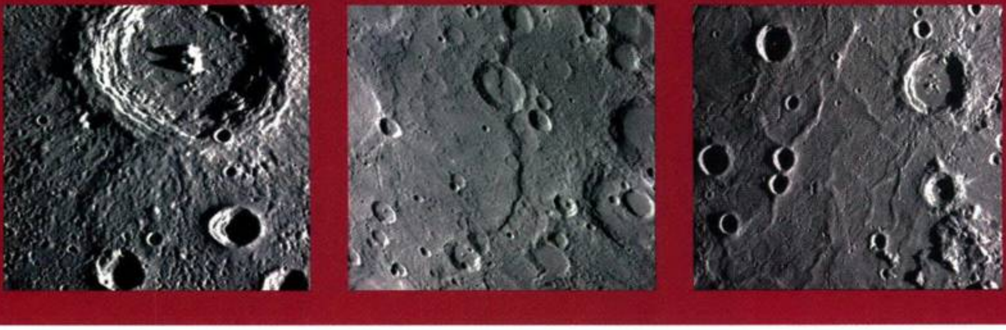
Maybe it's too small, or perhaps it looks just a little too much like the moon. Whatever the reason, minute Mercury rarely enjoys the limelight.

Pluto aside, Mercury remains the least-studied and least-appreciated planet in the solar system. Despite its proximity to the sun, Mercury tops very few "Best of..." lists. It's not the smallest planet — Pluto wins that contest. Nor is Mercury the hottest — that title goes to neighboring Venus. And it makes the "Top 10 planets in the solar system" list largely because there are slots to spare.

Mariner 10's first image of Mercury revealed a pockmarked surface similar to — but different than — the moon's. NASA/JPL/U. S. Geological Survey

Planet





Above: Mercury's southern hemisphere shows an abundance of fresh, rayed craters. NASA/JPL
Left to right: A 61-mile-wide crater shows a central peak and interior terraces; Discovery Scarp runs 220 miles and crosses two large craters; Ridges and fractures cover the floor of the Caloris basin. NASA/JPL/Northwestern University

At first glance, little distinguishes Mercury from any other rock in the solar system. It bears no icy rings, and no active volcanoes disturb its surface. It's not a potential abode for life and probably never will be. People have never been there and are unlikely to go. It's a planetary backwater — the Gobi Desert of the solar system.

To top it off, Mercury proves notoriously difficult to study. Viewed from Earth, Mercury never ventures more than 28° from the sun. This makes it visible to the naked eye only during morning or evening twilight, and then only low in the sky. Professional astronomers have it worse, observing the planet during daylight when it's higher in the sky. Most operators of large telescopes shudder at the thought of risking million-dollar optics for a fleeting glance at a small, barren rock perilously close to the sun. That's why the Hubble Space Telescope is forbidden to look at Mercury, lest the eyes of the most famous telescope in history get damaged. Radar offers the safest way to view Mercury, but that gives about the same resolution as Earth-based optical observations of the moon.

That leaves space missions. A year ago, NASA announced funding for the full-scale development of the MESSENGER probe to Mercury, set to launch in 2004. Not to be outdone, the European Space Agency plans an even more ambitious mission to the innermost planet late this decade. (See "BepiColombo: A European Flair," page 43.) Both missions aim to answer some long-standing puzzles about this enigmatic planet.

MESSENGER — short for MErcury Surface, Space ENvironment, GEochemistry and Ranging — marks NASA's first return to Mercury since Mariner 10. That pioneering mission, which flew past the planet a total of three times in 1974 and 1975, sent back the first glimpses of Mercury's surface. Yet Mariner 10 photographed less than half the surface, leaving scientists with a desire for more images that has gone largely unsatisfied over the last quarter century.

"Much of Mercury hasn't even been seen," says Ralph McNutt, Project Scientist for MESSENGER at Johns Hopkins University's Applied Physics Laboratory. "This is the first time we'll get high-resolution images of the unseen half. It will be like getting the first good images of the back side of the moon."

In past missions to other solar system objects, photos of the "other half" often revealed exceptional surprises. For instance, the first images of the moon's far side divulged a surface largely devoid of the dark, lava-filled basins visible on the Earth-facing hemisphere. More striking were the giant volcanoes on Mars, which remained undiscovered until the fourth mission to the Red Planet.

"When we've had other first glances, it is often not representative," says Clark Chapman, a planetary scientist at the Southwest Research Institute in Boulder, Colorado, and member of the MESSENGER science team. "The other half is largely *terra incognita*."

Even so, Mariner 10 revealed some very odd phenomena. MESSENGER and BepiColombo will visit a world where the temperature difference between night and day can reach over 1100° Fahrenheit (600° Celsius) at the equator. Scarps and cliffs, some more than a mile high, stretch across the surface, presumably a result of the planet shrinking as it cooled. Giant impacts blasted the pockmarked crust, marring it with craters. The largest of these impacts left the Caloris basin, some 800 miles (1,300 km) in diameter.

Mercury's "year," which lasts 88 Earth days, is almost exactly 1.5 times as long as its rotation period. Coupled with the planet's eccentric orbit — it differs from a circle more than any planet besides Pluto — this gives rise to some startling effects. As Mercury passes perihelion, its closest approach to the sun, its orbital speed surpasses its rotational speed.

That makes the sun appear to halt its motion in the sky and reverse direction, only to return to its course as the planet slows in its orbit. This phenomenon, known as retrograde motion, is similar to the effect seen as one car passes another on the highway. Even though both vehicles are traveling in the same direction, the passengers in the overtaking vehicle

The brightest crater on Mercury (at bottom center), measures 25 miles across and is named Kuiper after the famed planetary scientist. NASA/JPL

Areas of level to gently rolling ground cover much of Mercury. These plains range from fairly smooth to chock-a-block with craters. NASA/JPL

see the other car appear to move backward momentarily.

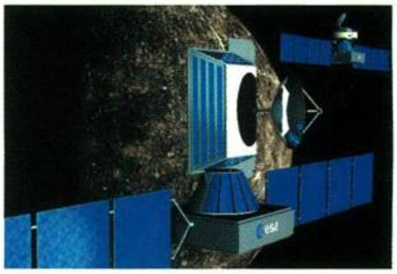
In light of recent discoveries of Jupiter-like planets orbiting close to their parent stars, Mercury's existence as a dense, rocky world orbiting close to the sun is as important to understand as why our planet is covered with water. It is, as Chapman calls it, an end-member planet, whose very existence brackets the spectrum of planet formation. To understand Mercury, why it is so dense, what it's made out of, and why it has a magnetic core, is essential to understanding our solar system as a whole, says Chapman.

"It is extreme in a bunch of ways," explains Chapman. "It is at the end of the spectrum in terms of bulk density, it is at the end in terms of distance from the sun, and it is also at the end in terms of temperature difference between night and day. It is extreme, and in science, one often learns from studying the extremes."

And there is still much to learn. "To the uninitiated," adds Chapman, "it looks a lot like the moon — but it is quite different." The formation and evolution of Mercury remain almost completely unknown, and the MESSENGER science team believes they may hold the key to understanding planet formation. Mercury represents the ideal physical laboratory. It is like, and yet completely unlike, any of the other terrestrial planets. "As a laboratory, Mercury changes the properties enough to test the generalities

BepiColombo: A European Flair

The European Space Agency has big plans for its own mission to Mercury. Under development as a "cornerstone" mission, BepiColombo promises to be one of ESA's most important long-term planetary projects. Named after Italian mathematician and engineer Giuseppe "Bepi" Colombo, who calculated the Mariner 10 spacecraft's trajectory, the mission aims to answer many of the same questions as MESSENGER. But it plans to do so in a unique way.

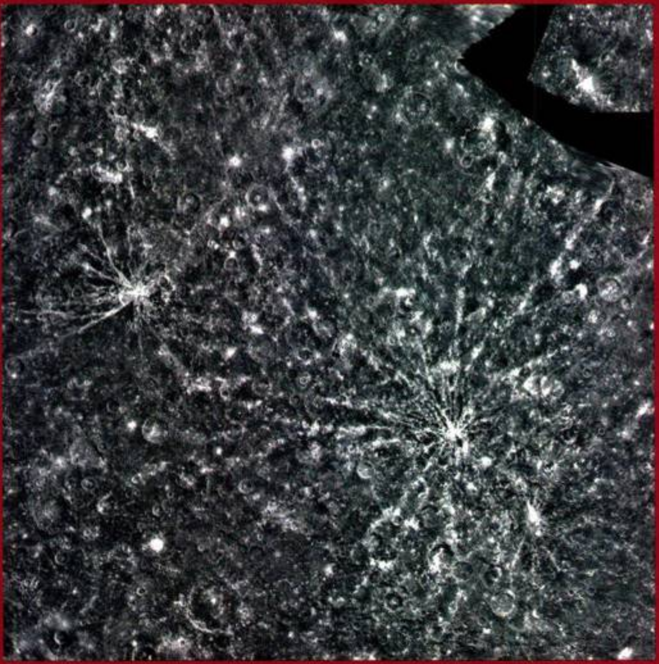


The BepiColombo spacecraft arrives at Mercury. European Space Agency

Preliminary studies envision sending three separate probes to the planet. The Planetary Orbiter will consist of two cameras and half a dozen other remote-sensing instruments that will examine Mercury from a polar orbit. A smaller Magnetospheric Orbiter will house seven instruments and observe the planet's magnetic field and its interactions with the solar wind.

Finally, a Surface Element will land near one of Mercury's poles. Its suite of instruments includes a camera, a seismometer, a detector to analyze chemical composition, and a package to measure the temperature, density, hardness, and heat capacity of Mercury's "soil." The Surface Element should operate for at least a week and the orbiters for about 12 months.

BepiColombo will use a different tack to gain the energy it needs to reach its orbit around Mercury. Although the flight path will take it past both Venus and Mercury for gravity assists, the spacecraft will also use a new ion propulsion system to provide a small but continuous acceleration for many months. A standard chemical propulsion system will ultimately place the spacecraft into orbit. Scheduled for launch in 2009, the mission will take two-and-a-half years to reach Mercury. — *Richard Talcott*



Bright rays emanate from the youngest, freshest craters on Mercury. These rays appear similar to those seen on Earth's moon . NASA/JPL

Mercury's south polar region displays innumerable craters that chronicle the iron-rich planet's violent history. NASA/JPL

of our models," says Sean Solomon, Director of the Department of Terrestrial Magnetism at the Carnegie Institution of Washington, and Principal Investigator on the MESSENGER mission.

But Mercury's proximity to the sun makes getting there difficult. At a distance of 35 million miles, the sun holds Mercury deep in its gravitational well. The change in velocity needed to get from Earth's orbit to Mercury's orbit makes a trip to the moon look like a walk to the pub. It's hard enough to lift a one-ton spacecraft out of Earth's grip at 6.9 miles per second, but the craft must then accelerate an additional 11 miles per second to match Mercury's much faster 88-day circuit around the sun. "Even though it is close by, it takes a lot of energy to get there," says Chapman.

Until Chen-Wan Yen, at NASA's Jet Propulsion Laboratory in Pasadena, California, figured out how to use gravity assists to get spacecraft to the inner planets, the cost in mass and propellant made getting a probe into orbit around Mercury prohibitive. After the Mariner 10 flybys, NASA shelved further missions to Mercury, in part because the agency didn't know how to get a craft into orbit without using vast amounts of fuel. With their atmospheres to help slow the arrival of incoming spacecraft, Mars and Venus became easier targets. Yen, however, changed all that. Like a sailor on the high seas, she devised a plan to use the natural forces generated by the planets to guide her ships into port. But instead of wind, Yen uses the gravitational energy of other planets to carry spacecraft into orbit.

"We use Venus and Mercury to shrink the spacecraft's orbit so we can get to Mercury and allow for an easy capture," says Yen. "MESSENGER is the most challenging because the energy change involved is large and the number of gravity assists one can consider are many."

This time, NASA's orbiter will allow a far more detailed study of the surface, making the added challenge worth the effort. Scheduled for launch in 2004, MESSENGER will steal energy from Venus and Mercury, making two flybys of each planet, before finally settling into orbit. With each visit, the craft siphons an infinitesimal amount of the planet's orbital energy to speed it on its way and ultimately maneuver into Mercury's orbit. This greatly reduces the number and duration of rocket firings, cutting the mass and total cost of the mission.

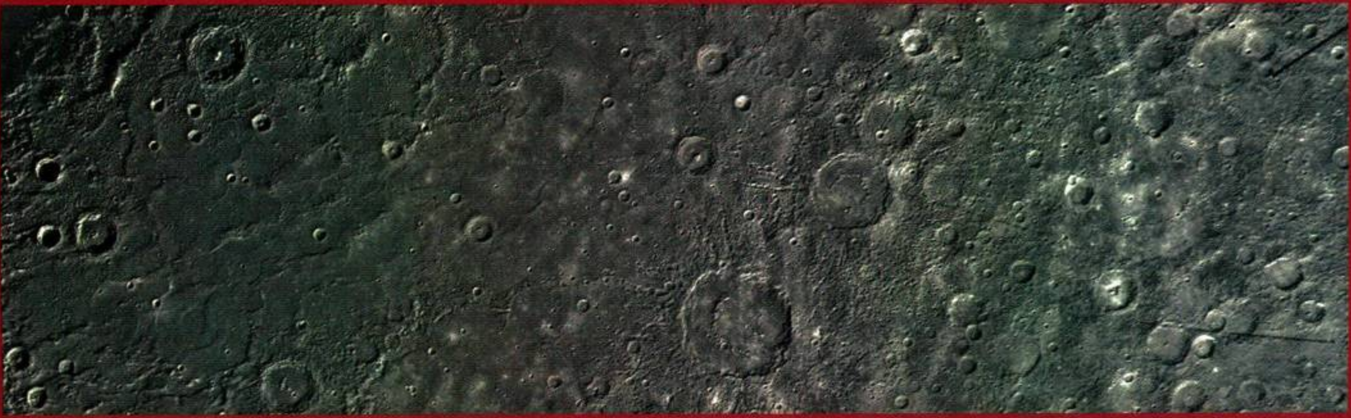
Of course, nothing in life is totally free. What MESSENGER saves in fuel it spends in time — nearly five years' worth — before reaching orbit in 2009. "By the time we reach orbit, it will have been almost 35 years since the last Mercury mission," says Solomon. "After Mariner 10, there was a great deal of interest in a Mercury orbiter, but nobody then knew how to put a craft into orbit around Mercury using conventional propulsion."

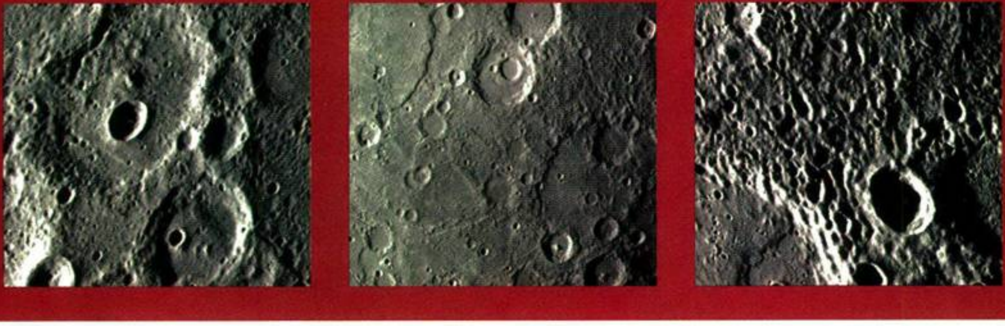
Even with all the help along the way, the spacecraft still requires a lot of old-fashioned rocket power. "MESSENGER, for the most part, is a flying fuel tank," says McNutt. "This is a very mass-constrained mission, and it's a hard mission to do."

But the MESSENGER science team certainly believes it is a mission worth doing. The team hopes to answer some fundamental questions about Mercury's composition and evolution in an effort to tie together competing theories of how planets form.

For one thing, Mercury, although just slightly larger than the moon, is nearly as dense as Earth. Larger planets use gravity to compress their material, which increases their overall density, but Mercury's small size indicates that the bulk material of the planet must contain a huge fraction of denser elements like iron. "We know almost nothing chemically about Mercury except that it is incredibly dense," says Solomon. "How did it get this way?"

Planetary scientists have concocted a number of theories to explain the high density. If Mercury formed near the sun, only the elements capable of condensing out of the solar nebula at high temperatures, like iron, would have been incorporated into the planet. Or, perhaps the sun's searing heat burned off the crustal material, leaving only a cinder of iron and nickel. It is even possible that





Above: Part of the 800-mile-wide Caloris basin fills the left side of this Mariner 10 image. NASA/JPL
Left to right: A young crater sits at the center of a much older one; A prominent scarp stretches hundreds of miles across the top left of this region; Craters pile on craters in many parts of Mercury.
NASA/JPL/Northwestern University

a giant impact knocked off the lighter crust as well as the underlying mantle, unveiling the metallic core.

Whatever the reason, MESSENGER's instruments should help answer the questions. Using x-ray, gamma-ray, and neutron spectrometers in conjunction with visible and near-infrared measurements, the team expects to pin down the planet's surface composition. "We know the bulk density of Mercury, but as for actual minerals on the surface, we really don't have a clue," says Chapman.

And those clues are important to understanding the formation of the planet, according to McNutt. "The spectrometers will give us our first good look at the properties of the surface," he says. "Potentially, there is a rich scientific harvest to come out of this."

The team also hopes MESSENGER will answer other pressing questions about surface materials. In 1991, radar images showed highly reflective regions deep inside craters near the poles of Mercury. "We want to know what this material is," says Solomon, "and we are applying a number of remote sensing techniques to find out."

The top culprit may be surprising: "The best guess is that water ice lurks just inches below the surface at the poles," says Chapman.

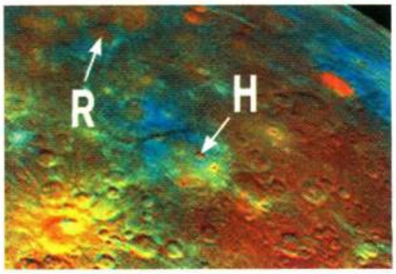
Unlike Earth, Mercury's axis tilts exactly 90° to the planet's orbit around the sun. At the poles, therefore, the sun

Seeking the Volcanic Plains

Bright and colorful may not be words normally associated with Mercury, but it all depends on how you look at it. More than two decades after the Mariner 10 flybys, Mark Robinson of Northwestern University and Paul Lucey of the University of Hawaii reanalyzed the old data to create color maps showing differences in composition across the planet's surface. The images reveal a dynamic planet that likely once experienced lava flows and explosive volcanic eruptions.

Planetary scientists had long suspected that Mercury experienced a volcanic past, though they had no way of knowing for sure. Venus, Earth, the moon, and Mars all have large tracts of relatively smooth terrain covered with lava, and all except the moon possess large volcanoes. Although black-and-white images of Mercury revealed smooth plains that appeared similar to the lava-filled lunar maria, looks can be deceiving.

Robinson and Lucey's images, created from Mariner 10 data at two wavelengths, helped make the case. An area near the crater Rudaki (labeled R in the false-color image) makes a good example. Suspected lava flows west of (above) the crater appear red, which suggests a low amount of titanium. This stands in marked contrast to its surroundings — a key sign that lava flooded the region and buried material of a different composition.



False-color images suggest Mercury had a volcanic past. NASA/JPL/Northwestern University

A more explosive origin appears likely for material near the Homer basin (labeled H). Robinson and Lucey suspect that a weakness in the crust became a fissure that allowed magma to reach the surface, where it erupted explosively. The boundaries of the blue material to the upper left of the basin appear diffuse; just what would be expected from such an eruption. — *R. T.*

A Long and Winding Road

1] MESSENGER begins its historic voyage on a Delta II rocket currently scheduled for launch on March 10, 2004.

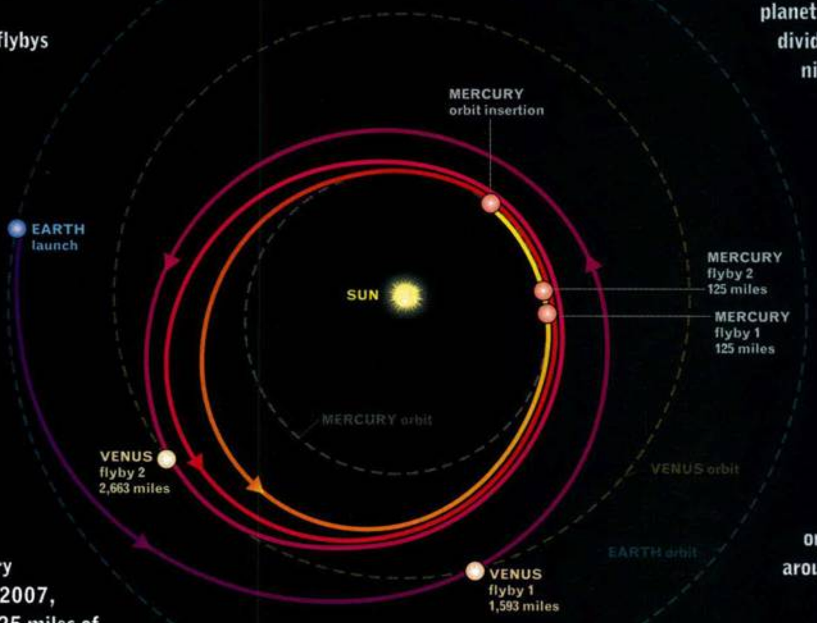
2] The first of two Venus flybys occurs just three months later, on June 24. The spacecraft approaches Venus from the night side and passes 1,593 miles above the planet's surface.

3] After three trips around the sun, MESSENGER once again encounters Venus, on March 16, 2006. It zips past the day side at an altitude of 2,663 miles.

4] The first of two Mercury flybys arrives on July 21, 2007, when it dips within just 125 miles of the planet's surface.

5] The second Mercury flyby comes on April 11, 2008, once again at an altitude of 125 miles. The sequence of four planet flybys (and two firings of the onboard rocket) will allow the spacecraft to match the innermost planet's orbital velocity. At both Mercury flybys, MESSENGER will approach the planet near the terminator (the dividing line between day and night) and depart from the day side. These sunlit views will give scientists their first close-up views of the half not seen by Mariner 10 and help plan observations once the spacecraft achieves orbit.

6] MESSENGER arrives at Mercury for the final time on April 6, 2009. The spacecraft will fire its engine once again to achieve orbit around the enigmatic planet.



MESSENGER's science team plans to put the spacecraft into a highly eccentric, 12-hour-long orbit that comes within 125 miles of the planet's surface at closest approach and goes out as far as 9,440 miles. The mission should last at least one Earth year.

remains forever on the horizon, and the bottoms of deep polar craters never see sunlight. Ice that collected there, from comet impacts or other sources, would never melt, even on one of the hottest planets in the solar system.

Perhaps more important is Mercury's magnetic field. According to Solomon, the other two small objects in the inner solar system exhibit only weak signs of magnetic activity. The moon once had a magnetic field, and Mars shows evidence of having had one early in its history, but neither object currently possesses a global magnetic field. Mercury, on the other hand, halfway in size between the moon and Mars, has an active and relatively strong magnetic field.

Why tiny Mercury should be magnetically active continues to be one of the great unanswered questions. Planetary scientists think that planets require a liquid core to sustain such a field, but the smaller the planet, the faster it cools. Mercury, by all rights, should have a core as cold and dead as the moon's. Yet the magnetic field persists. According to the science team, this may result from the existence of elements like sulfur that, when mixed with iron, lower the melting point and keep the core molten. Determining the state of Mercury's core is one of the primary goals of the mission.

Mercury's magnetic field also creates the only other Earth-like magnetosphere in the inner solar system. "Mercury has a miniature Earth's magnetosphere," says Solomon. The magnetosphere interacts with the solar wind, creating a physics experiment studied in detail, so far, only on Earth. "The dynamics are very similar to Earth's magnetosphere, but much faster," according to Solomon.

Mercury should provide an extraordinary physics laboratory. Planetary astronomy aside, it has been a proving ground for Einstein's theory of general relativity. Observations of Mercury in the last century supported the theory, because it explained perturbations in Mercury's orbit that were unexpected in Newton's classical theory of gravity. MESSENGER, as the first artificial satellite to orbit this close to the sun, may provide more information. "By simply having a spacecraft that near the sun, we will be learning things relevant to gravitational physics," says Solomon.

After 25 years of neglect, humans are finally rekindling their interest in Mercury. MESSENGER and BepiColombo stand to answer some of the most vexing questions in planetary astronomy. With new planets being discovered around other stars every month, developing a detailed understanding of our own solar system becomes even more important. Mercury, long ignored as the boring sibling in a solar system burgeoning with superstars, is finally drawing attention. The next decade should bring Mercury's moment in the sun. ■

Animations of MESSENGER's path on the way to Mercury can be found on *Astronomy's* October issue page at www.astronomy.com.

John Armstrong is an astronomy graduate student at the University of Washington. This is his first article for Astronomy.

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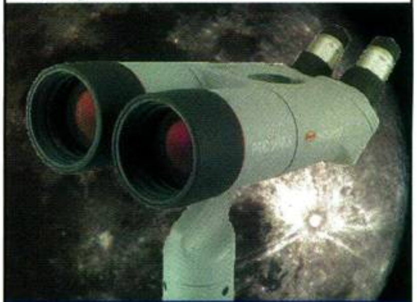

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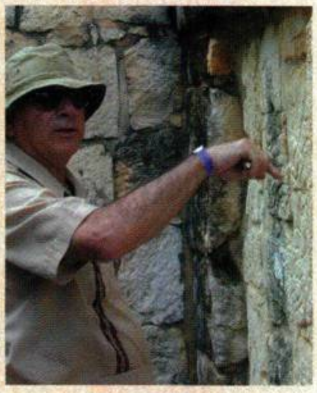
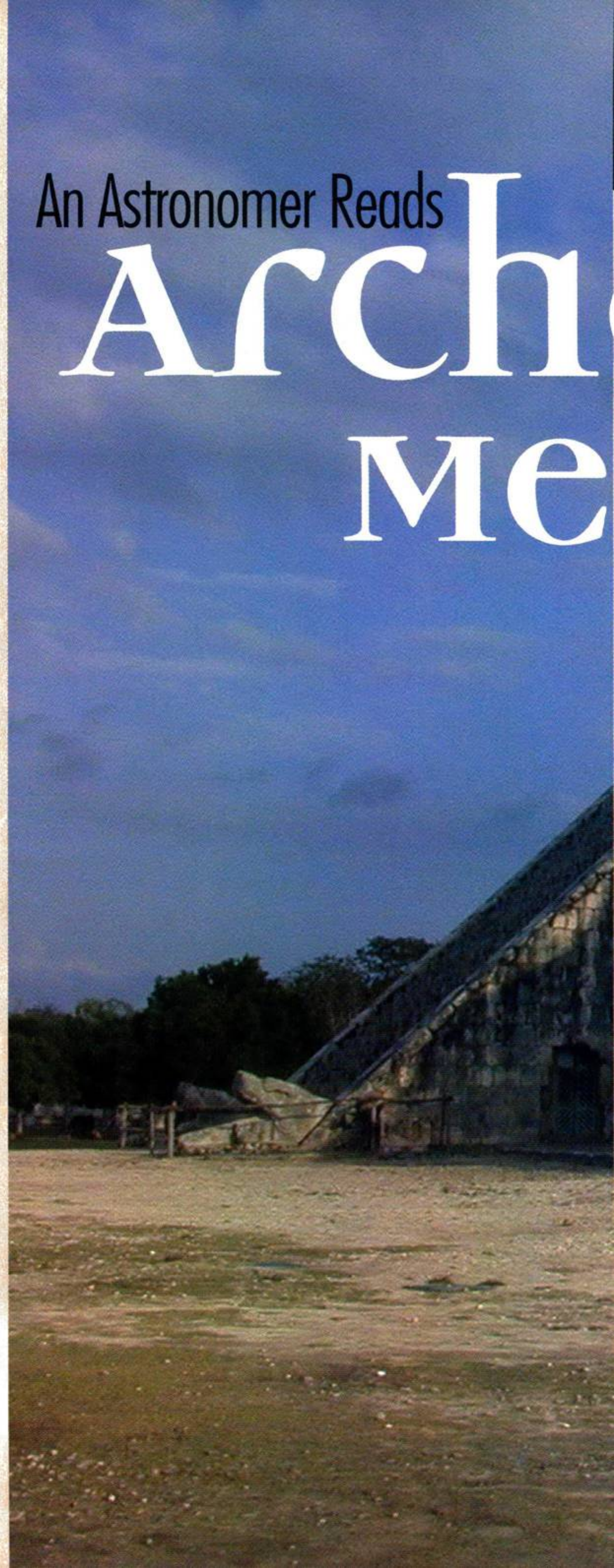
An Astronomer Reads Arch Me

Anthony Aveni takes the "road less traveled" to decipher the secrets of ancient cultures.

by Patricia A. Kurtz
all images by Peter Sutter

Ancient ruins, like Rorschach inkblot tests, often reveal more about the beholder than they do about the objects themselves. Lines and drawings carved into a Peruvian desert a couple of thousand years ago inspired Erich von Daniken to suggest they served as runways for alien spaceships. This was the 1970s, and Anthony Aveni, then an astronomy professor at Colgate University in Hamilton, New York, was painstakingly searching for evidence of the truth. While von Daniken and others looked at drawings and photos to reach their otherworldly conclusions, Aveni took a research team out to the Pampa de Inge-





Above: The past is literally set in stone for archaeoastronomer Anthony Aveni, who uses scientific and anthropological techniques to decode it. Right: The silhouette of a serpent appears on a Mayan pyramid on vernal and autumnal equinoxes.

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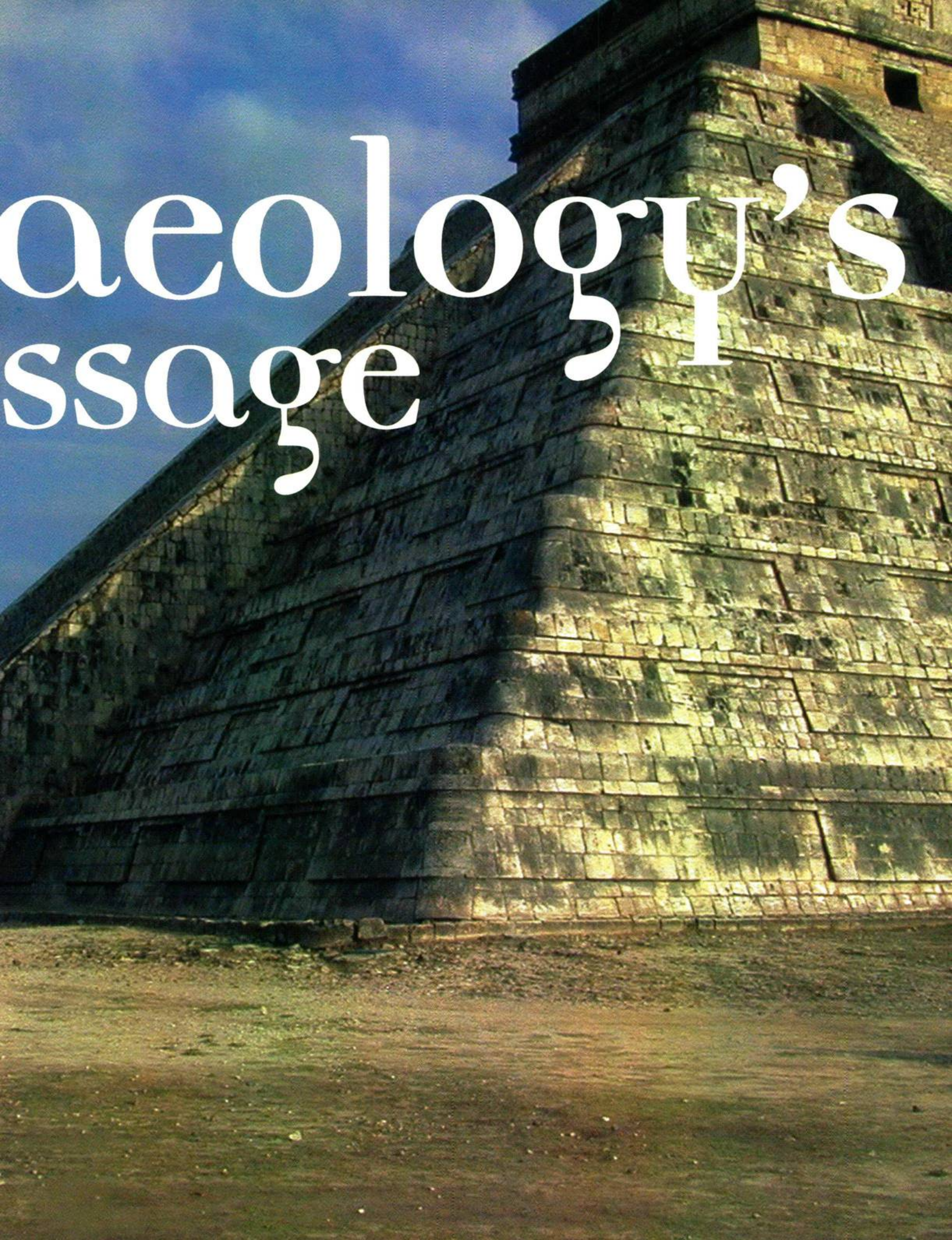
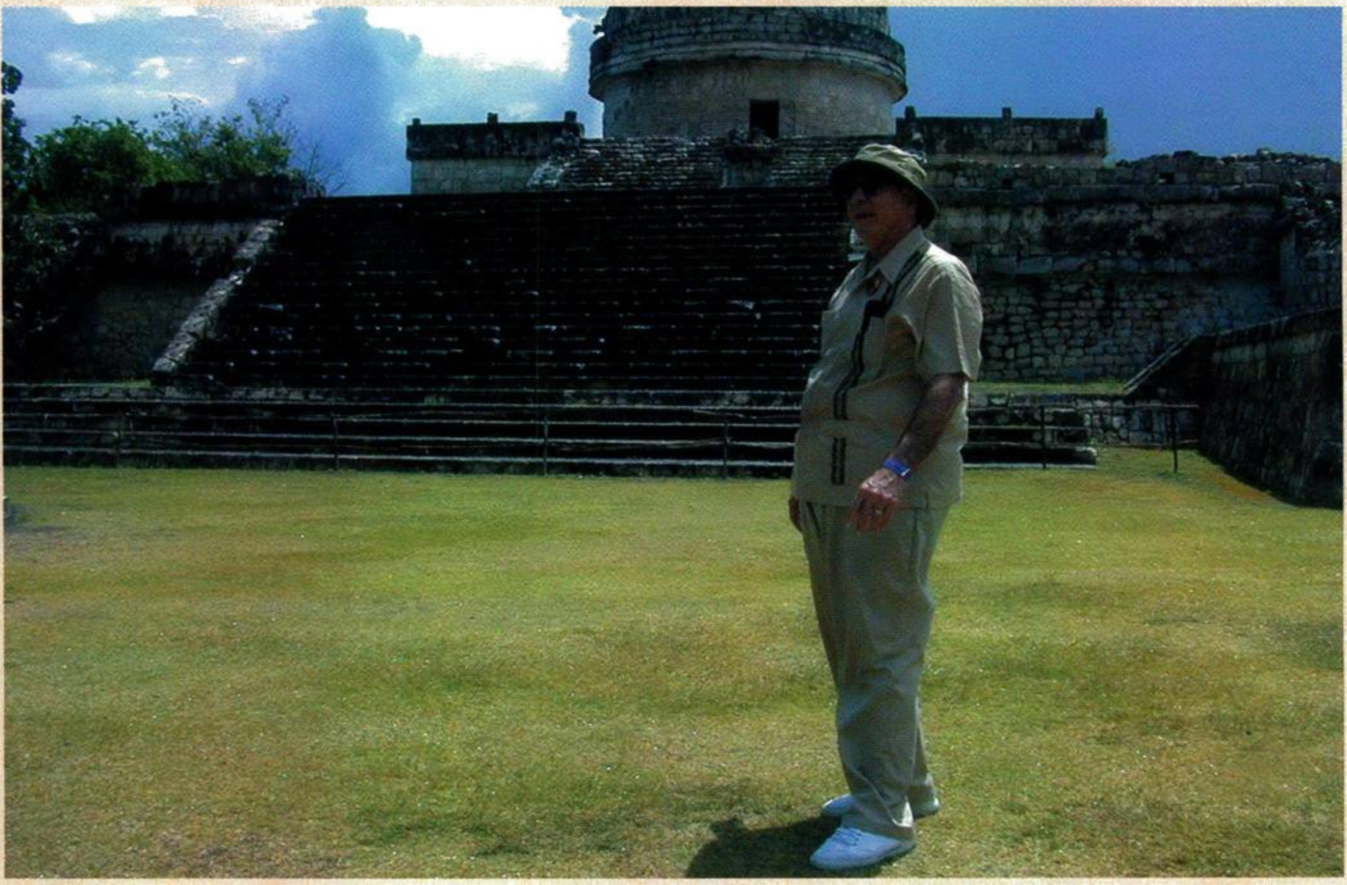




Aveni stands before the 10th-century Caracol Observatory (at top of stairs), which has windows facing Venus's rising and setting points. Based on ancient texts and accounts from 16th-century Spanish priests, archaeoastronomers know that Venus was very important to Mayan culture.

nio. There he discovered earth etchings that formed giant birds, spiders, monkeys, and more. He and his team measured the orientation of 762 straight lines (some of them up to eight miles long) and more than 60 raylike hubs of lines. They analyzed their plots with a computer and found that many of the lines point to the "sun's place on the horizon at the beginning of the rainy season." Some 2,000 years ago, people may have walked on the lines and performed some kind of ceremony "connected to the ritual acquisition of water."

In a recent issue of *Archaeology* magazine, Aveni concedes his theory isn't as dramatic as an extraterrestrial landing pad. "As much as the lines awe me," he writes, "I marvel equally at the imagination of the people who have sought explanations for them."

Despite his lengthy research in Peru (see "Stairways to the Stars: Skywatching in Three Great Ancient Cultures" — *Astronomy*, November 1997), Aveni's expertise lies in the Mayan civilization in Mexico, where he began his foray into archaeoastronomy. Colgate University had a January term during the late 1960s, and its emphasis was on experiential learning, not just collecting facts.

"In those days," he says, "you were supposed to do daring things, take students into the field to do things that hadn't been done before. We came up with this crazy idea to go to Mexico to study the orientation of pyramids. We figured it was also a good way to get out of the cold climate of the northern United States.

"We piled eight students into a van and got as far as the Monte Alban site in Mexico where there's a five-sided pyramid. All the literature about this pyramid reported that the axis of this monument was an indicator of sunset at solstice. Since we were there very close to solstice, we begged permission to stay at the site all night, watch the sunset, and so on. To make a long story short, we did, and the sun didn't. Instead of setting over here [he jabbed his finger towards an imaginary point on the western horizon], it set over there. It was about 40° off. When we confronted the site guide about the discrepancy, he said, 'Well, I don't know, that's what the guide book says.'

"We really initiated the idea of going to the site and making measurements," says Aveni. He and his students were the first to take a hard look at claims made about the pyramid. He says, "People had just accepted it. We started meeting archaeologists who said, 'You know, you measured this one — you should go to our site next year and measure that one.' I was hooked. I've been taking students down there for 32 years. Since we no longer have a January term, I tell my students that my *spring semester course* will start three weeks early in Guatemala City and they should be there. They go and we do field work."

By training, Aveni is an astronomer, having received his Ph.D. from the University of Arizona. He worked as a spectroscopist with emphasis on galactic structure, T-Tauri stars, and star formation. Six years into his career at Colgate, he switched to archaeoastronomy.

"That trip to Monte Alban opened an entirely new area to me because I had never been aware of what ancient people were doing," he says. "When you teach astronomy, you're naturally interested in where astronomy came from." Now he holds a chair in astronomy and anthropology at Colgate. "Astronomers study stars, anthropologists study people; I study people who looked at stars," he says.

> "Our way of understanding the world is not the only way. Nor is it even the preferred way."

Aveni defines archaeoastronomy as the practice of astronomy using both the written and unwritten record. He emphasizes "unwritten," because in studying Old World astronomy such as that of Galileo or the Greeks, "We glean all our information from texts, and we don't pay attention to the archaeological record, or the iconography, the sculpture. Archaeoastronomy combines all of these ways of understanding the sky, and it goes beyond the equations or written descriptions." In the unwritten category, Aveni includes alignments of the windows or shafts of a building, the spatial relationship among pyramids, and many other design issues.

He agrees that there's another side to archaeoastronomy — the cultural aspect. "People talk about the 'lost culture of the Maya,' but they're not lost," he says. "There are 29 Mayan dialects spoken by two and a half million people in the Mayan area. We can learn about their language, their mathematics, their world view, and their astronomy, by talking to them."

Aveni says that his students often worry that Mayans, Aztecs, and the Inca didn't know about the Earth and planets orbiting the sun. He tells them that given their backgrounds, those cultures wouldn't have cared about that question, which comes from ancient Greece. It's in Aristotle's political writing — not his physics — where the philosopher describes the organization of space, as well as of social classes, as orbs orbiting a center, says Aveni.

"So, if we lived in ancient Greece, you and I would sit in a coffee shop and contemplate the hierarchical arrangement of culture according to this orbital model," says Aveni. "And, it's from that model that the Greeks took license to discuss the matter of how the heavens are arranged hierarchically. What's the center and what's not the center? From that, Copernicus got his idea of the sun being the center, and from that Niels Bohr got his idea of the nucleus being the center of the atom with an electron moving around it. Culture influences how you think about nature. You can't study nature without culture."

He adds, "Our way of understanding the world is not the only way. Nor is it even the preferred way. Nor does it even have any advantages over any other way of understanding the world. I think that the way one understands the world is tied to who they are, and that includes us."

Aveni would like to see archaeoastronomers become more skeptical with regards to certain claims at "archaeoastronomical" sites. He feels they would be more skeptical if they knew more about the culture in question, and that we should ask ourselves how a particular people were going to use the knowledge we think they were using. Using research at Stonehenge as an example, he says, "All this stuff about extremely precise lunar alignments and eclipse predictions — I don't think it washes. I don't think people who lived in the Bronze Age would care much about predicting eclipses. What's the advantage to it? But, would they care, would they be concerned about having their sacred space lit night and day by the sun and the moon, in alternate roles rising and setting opposite each other? Yes, I think that's very likely. That's an example of the kind of question archaeoastronomy should ask. I think alot of archaeoastronomy is about erecting cardboard ancestors of ourselves." People do things to meet needs, he explains, so archaeoastronomers should be looking at what the needs of the culture were that caused them to do or create certain things.

"Gerald Hawkins once said of Stonehenge something like, 'If I can see anything in these stones it must have been known to the ancients.' I don't agree with that. If I see anything in the stones, I don't know that they knew it. I have to be able to demonstrate that they knew it. The only way I think we can do that is with statistics — we have to use statistics to show that these arrangements and alignments occur at a statistically significant level so that we can believe they're not coincidental. It's dangerous to use contemporary knowledge when you don't know for sure how much continuity there is in the culture. We like to think there's continuity in culture because that would be cool, but we don't know it. If we have evidence for it, we can use it. That's why

Archaeoastronomers use gestalt theory to assemble a picture of the past, piecing together clues from the alignment of buildings to the symbols on reliefs such as this one.

Archaeologists are still unearthing ancient Mayan monuments, like this one to Kukulcan, the serpent god, in Chichén Itzá, Mexico. Thousands of visitors crowd its base every March on the vernal equinox to watch a shadow-snake appear along the steep staircase.

I like to work with Maya. You can make some hypotheses. On the other hand it's difficult because you have to know about the writing."

Aveni doesn't like to take a "scatter-gun" approach to interpreting a site. One of the reasons he went to Teotihuacan, where the great pyramids of Mexico reside, was to study carved petroglyphs in the shape of a double circle with a cross, resembling a target. These symbols were pecked into rocks and onto the floors of some of the buildings. Earlier researchers believed that some of these markers could have functioned as architectural benchmarks to align the city.

Aveni's team set out to precisely measure the lay of the land, surveying the orientation of the city. "We found these markers everywhere. So, we had to map all of them, then we used statistics.

"I don't go into a site and say, 'There's a nice pyramid, and there's a bump on the horizon. That must be an alignment. If I find one that works I don't say I discovered something, all the while ignoring the other 37 bumps on the horizon that don't work with anything. I don't do that."

A number of projects are on the horizon for Aveni, including work with epigraphers Victoria and Harvey Bricker at Tulane University, experts on Mayan writing. Part of their research will involve a set of pages in the Mayan Dresden Codex in which they've discovered a Mars table.

His most challenging work deals with Mayan writing, which he reads "moderately well." He finds it interesting to study Mayan mathematics and their axioms and principles in mathematics. "It's challenging to try to reconcile what we see in the written works with what we see in the architecture," he says. "By comparison, measuring alignments is easy. Maybe you can find a pattern. Maybe it's true, maybe it's not true, and that's fun. But when you get the information from the culture, you have to try to mesh it with the science."

Married for 42 years, Aveni and his wife Lorraine have two children (not astronomers, he assures me) and a 13-year-old grandson who recently accompanied him into the field. While Aveni will take a semester away from Colgate in 2002 to work with the Brickers, he still loves his students and it shows. In 1982 the Council for the Advancement in Support of Education in Washington, D.C., named him the National Professor of the Year. In 1991 he was listed in *Rolling Stone*'s list of Top Ten Professors in the country. I asked him what he hopes his students take with them upon leaving his class, and he responded, "Passion. Passion for anything. I don't care if they do what I do; we don't need a world full of archaeoastronomers. If I can help them to love music … that's great." ▪

Patricia Kurtz, a contributing editor to Astronomy, *credits the writings of Aveni and a couple others in the field with getting her involved in astronomy.*

An Archaeoastronomer's Tour of Mayan Country

In the remains of the Mayan city Chichén Itzá, light and shadow mingle twice a year to reveal a serpent uncoiling down the stairs of the central pyramid. It happens at equinox, when our swiftly tilting planet passes through two points along its orbit of the sun. At those points, day and night balance each other perfectly, a yin and yang of light.

The pyramid testifies to the importance of the sun and planets to the ancient Mayans. And it is still important today — many Mexicans, not to mention foreign tourists, visit the monument to the plumed serpent god Kukulcan for the annual unfurling of the snake. On March 21st of this year, 60,000 pilgrims came to see the fleeting mural along El Castillo, the pyramid's Spanish name. (The snake also forms on the balus-trades at autumnal equinox, but to lesser hoopla.)

The date of the Vernal equinox coincides with the birthday of Mexican hero Benito Juárez, celebrated officially by the Mexican government at Chichén Itzá. In addition to birthday celebrants, people visit the site out of astronomical interest, amazed at the proposition that the builders of the pyramid could have aligned the building so perfectly to mark the new season. Many of the two million living Mayans come to keep the traditions of their culture alive.

To learn more about multicultural astronomy, visit Astronomy *magazine's October issue page at www.astronomy.com.*

The shadowy snake almost perfectly unfurls on the stairs for a few days on either side of equinox. On March 23, archaeoastronomer Anthony Aveni served as our guide to the ruins of Chichén Itzá, paying special attention to those that used astronomical references. That day several hundred people turned out to witness the ephemeral phenomenon, despite the tropical downpour that had dampened our plans all day. We gathered before Kukulcan pyramid at 4 P.M. and began our wait, hoping for a bright sun, without which the snake is not visible. We were not disappointed — the sky cleared almost magically just at the crucial moment.

During the week of the equinox, no one is allowed to climb Kukulcan pyramid, so this time we watched from its base. But to get a good view of the building, the city, and the whole Yucatán peninsula, it's really necessary to climb to the top. Each of its four sides holds 91 steps, and one more step gains admission to the temple. The total is 365 steps, matching the days of the solar year. Nine terraces separate the stairs into 18 sections, matching the Mayan month, and each of 52 panels above the terraces marks a year, adding up to the equivalent of a Mayan century.

The ascent is steep, though nowhere near as precipitous as it seems on the way down, when many people cling to centrally located chains for support.

Chichén Itzá began as a farming village in about 500 A.D. However, most of what remained of the city, including the central pyramid, was built later, during the post-classic Mayan period. The pyramid's external walls are about 1,000 years old, though underneath the most recent construction reside smaller, older pyramids, each one built around the other by a subsequent ruler. Pyramids of the classic period (200-950 A.D.), like the ones at Tikal in Guatemala, are steeper still, and at Tikal's tallest and steepest central pyramid, it is too steep to climb.

From the temple level near the top of Kukulcan, you can survey nearly all the ruins of Chichén Itzá. You can see the Observatory, the Temple of the Warriors, the group of a thousand columns, the Venus Platform, the largest Mayan ball court in Mesoamerica, and the nunnery. Trees and vines around the buildings create a quilt in shades of green that expands out to the end of visibility. The land is flat in every direction. Where there are small rises in the landscape, it seems another as-yet-unexamined temple resides, buried in vegetation. (This explains why the largest Mayan site in all of the Yucatán, the city that once ruled even Chichén Itzá, has revealed itself only recently.)

Anthony Aveni spends almost every vernal equinox here as a guest of Royal Olympic cruises, for whom he lectures on the connections between people and the sky. He is one of three archaeologists every year who tell visitors about Mayan culture as they cruise through the Caribbean. On this trip to Chichén Itzá, he has pointed out the Venus Platform, the perfectly aligned Observatory, and dozens of the hieroglyphs throughout the ruins that celebrate the sun, Venus, and other planets.

On this trip, Aveni is accompanied by Rebecca Storey, a University of Houston physical anthropologist, who studies human bones from pre-Columbian civilizations and has supervised the study of 600 skeletons excavated at Copan in Honduras. (She tells us that the human remains found in so many Mayan cenotes, or sacred wells, were not only young, female virgins, as visitors are often told, but also included men and people of all ages.) In addition, her husband and colleague at the university, Randolph J. Widmer, is along to discuss a broad range of research interests, including the relationship between the Mayan builders and the environment.

In 2002 Royal Olympic offered a ten-day cruise that began with a tour of Chichén Itzá at vernal equinox. Along the way, outings are offered to take visitors to many other Mayan ruins, including Tikal and Quirigua in Guatemala, Copan in Honduras, and Tulum and Coba in Mexico. Each of these Mayan sites provides intriguing details that link the culture with the sky. In 2003, the cruise line plans a seven-day trip with fewer stops. Alternatively, you may want to visit these ruins at your own pace, without a tour. Their aesthetic appeal combined with the ingenuity of the builders invite introspection and inspire awe. — *P.K.*

sky Show

October 2002

Night of the Gas Giants.

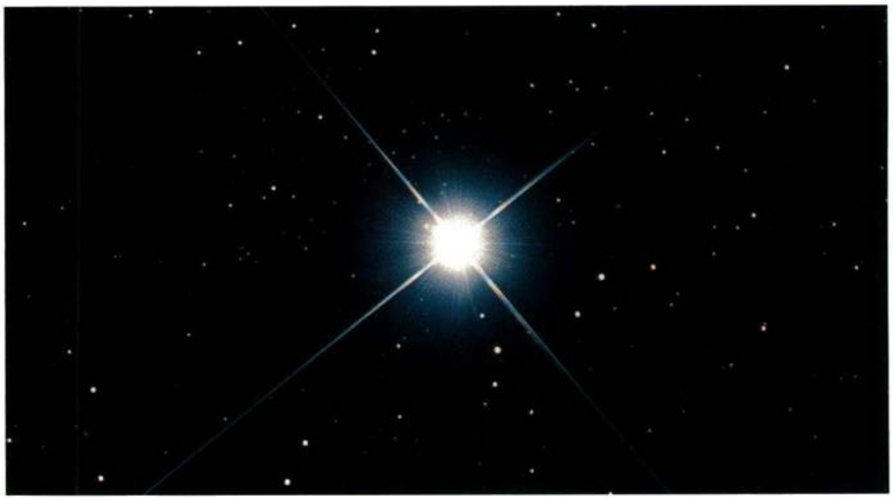
by Martin Ratcliffe and Alister Ling

▶ Amateur astronomers from pole to pole have been eagerly awaiting the return of the bright planets to the celestial stage. Other than June's magnificent Venus-Jupiter pairing, planet watchers have had little to cheer about lately. But this month the spectacular planet Saturn rises in the late evening sky, while the always-impressive Jupiter clears the horizon near midnight.

While waiting for these planets to climb up and out of the turbulent air masses that blanket the horizon, take the opportunity to focus on our solar system's other gas giants. Uranus is surprisingly bright — easily visible in binoculars from the city, though its light appears rather flat compared to starlight of similar magnitude. Even through the smallest telescopes Uranus shows off a very unusual greenish hue. The more distant Neptune appears fainter and smaller. You may want to use charts to identify which "stars" are actually these two planets. In good seeing, you can crank up the power and observe their tiny disks. On a great night with a 10-inch scope you may even glimpse some of their moons.

Venus is all but gone for observers in the Northern Hemisphere — it sinks into the glare of the sunset glow. However, Southern skywatchers will be able to cast their shadows by the light of our blazing planet as it hangs modestly high in the sky just after dusk.

Mercury puts on an exhibit in the second week of October. (We'll show you just when and where to look, so it will be a snap to see.) In fact, by October 10, you should be able to glimpse the innermost planet with the naked eye. As an added bonus, a faint Mars reappears from behind the sun and slowly climbs past Mercury. Catch the speedy little planet while you have the chance, for it'll drop out of sight for some time by the third week of October.



Outshone only by the sun, Sirius is the brightest star in our night sky. John Chumack

Those who live on the seaboard are well aware of tides. Thanks to two astronomical phenomena on October 5 and 6 the biggest tides of the year occur. First, the sun and moon are gradually lining up with Earth so that their collective gravitational pull is exceptionally strong. But more importantly, the moon reaches perigee — the point in its orbit where it's closest to Earth — early this month.

At full phase (October 20–21) we're lined up again, but this time the full moon will be at apogee — its greatest distance from Earth. If you took a picture of the big full moon back in February as we suggested, then make sure you snap another shot with the same photographic setup so you can see how much smaller the moon appears at apogee.

Observers in much of North America are well placed to see the sky's brightest star, Sirius, after sunrise. It lies due south as the sun crests the horizon, and with clear skies and a little patience, you can follow Sirius for about an hour into daylight. Some people will find polarizing sunglasses helpful in viewing such a bright object.

The Orionid meteor shower is one of the more active and reliable annual events. Unfortunately, this year the peak occurs during a full moon, thereby compromising the visibility of Comet Halley's swift dust particles burning up in our atmosphere. Instead, spend this time planning a backup strategy in case it's cloudy for next month's Leonid storm, which you won't want to miss. Even with a bright moon, you should still see a few hundred meteors an hour over most of the Americas.

If you're up for a dark-sky challenge on the weekend of October 5, track down Comet RX14 LINEAR among the galaxies of Lynx, near the feet of Ursa Major. By the end of the year, this comet is expected to glow near a presentable magnitude 10. Another reward for staying up until dawn is a thin crescent moon — almost 24 hours from new — rising in the east with Mercury and Mars. The trio will squeeze together in the field of most 7x50 binoculars.

Please consider sharing the night sky with goblins and witches on Halloween night, October 31. Since we're fresh out of bright planets and the moon, show them bright double stars like Albireo, Alcor, and Mizar, and then some sparkling star clusters like M11.

October 2002

2 The moon passes 4° north of Jupiter, 3 A.M. EDT

3 Asteroid Juno is in conjunction with the sun, 6 P.M. EDT

4 Asteroid Ceres is at opposition, 4 A.M. EDT
The moon passes 4° north of Mars, 9 P.M. EDT

6 New moon is at 7:18 A.M. EDT
The moon is at perigee (221,779 miles from Earth), 9:17 A.M. EDT

8 The moon passes 10° north of Venus, 6 A.M. EDT

10 Venus is stationary, 5 A.M. EDT

11 Saturn is stationary, 9 A.M. EDT

13 First quarter moon is at 1:33 A.M. EDT
Mercury is at greatest western elongation (18°), 4 A.M. EDT

14 The moon passes 5° south of Neptune, 10 A.M. EDT

15 The moon passes 4° south of Uranus, 6 P.M. EDT

20 The moon is at apogee (252,500 miles from Earth), 12:40 A.M. EDT

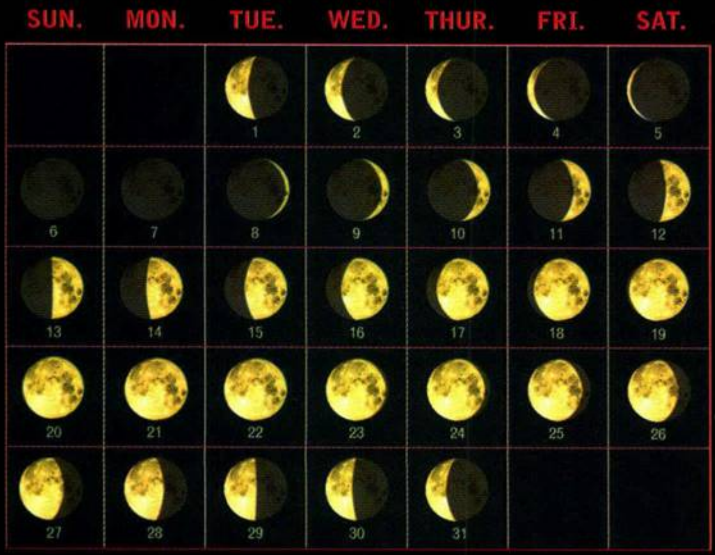
21 Full moon is at 3:20 A.M. EDT
Orionid meteor shower peaks

26 The moon passes 3° north of Saturn, 5 A.M. EDT

27 Mercury passes 4° north of Spica, 4 A.M. EST

29 Last quarter moon is at 12:28 A.M. EST
The moon passes 4° north of Jupiter, 5 P.M. EST

31 Venus is in inferior conjunction, 7 A.M. EST
The moon passes 1.3° north of Vesta, 7 P.M. EST


SUN.
MON.
TUE.
WED.
THUR.
FRI.
SAT.
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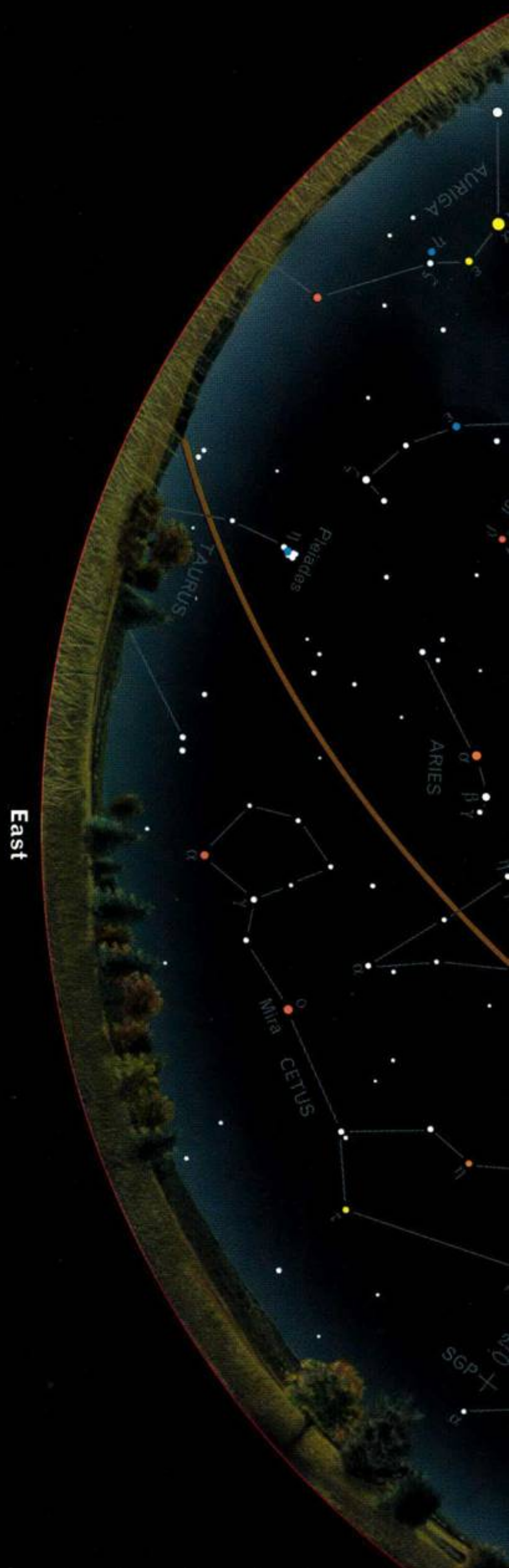
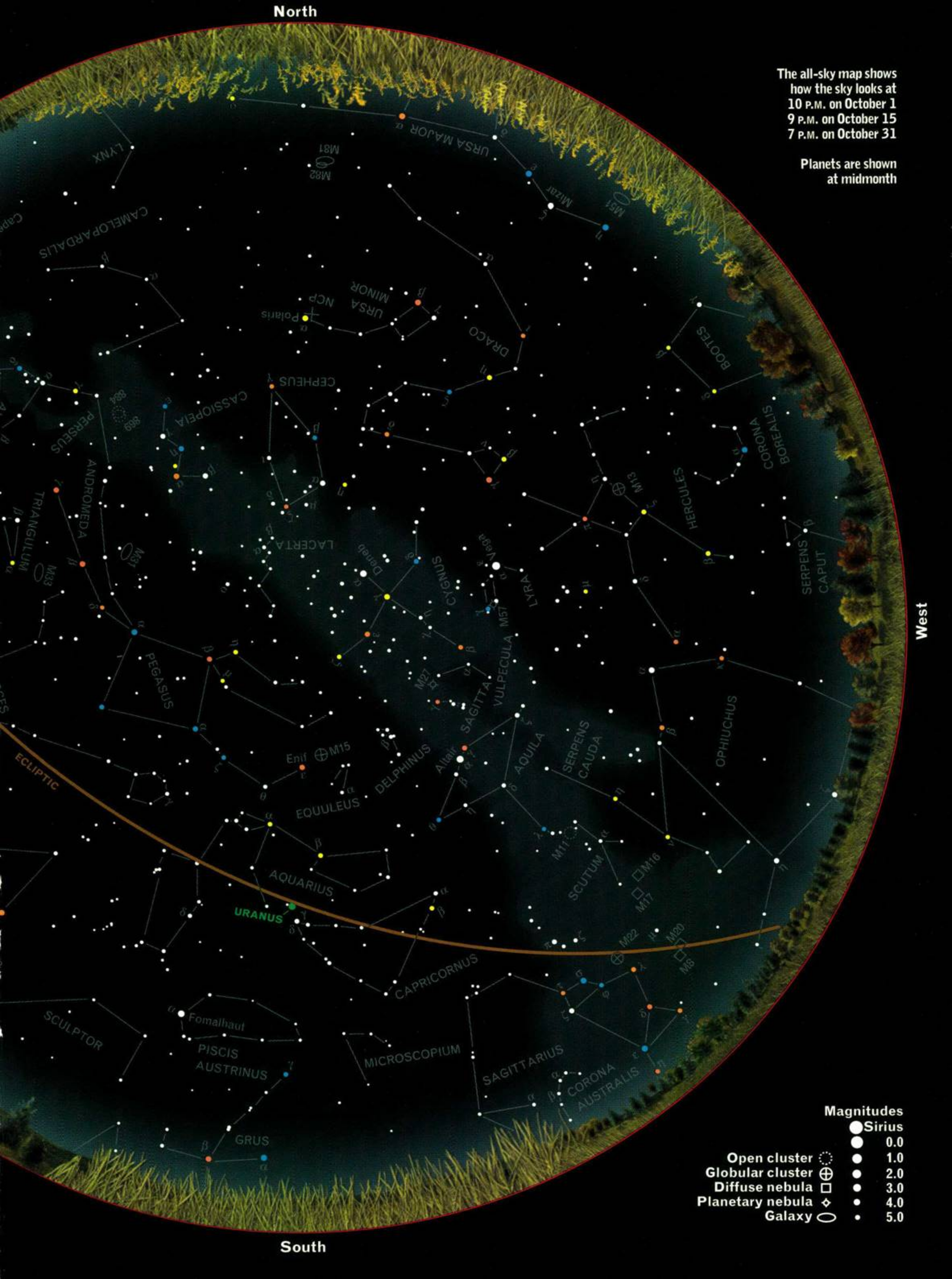

East
AURIGA
Pleiades
TAURUS
ARIES
Mira
CETUS
SGP

This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.



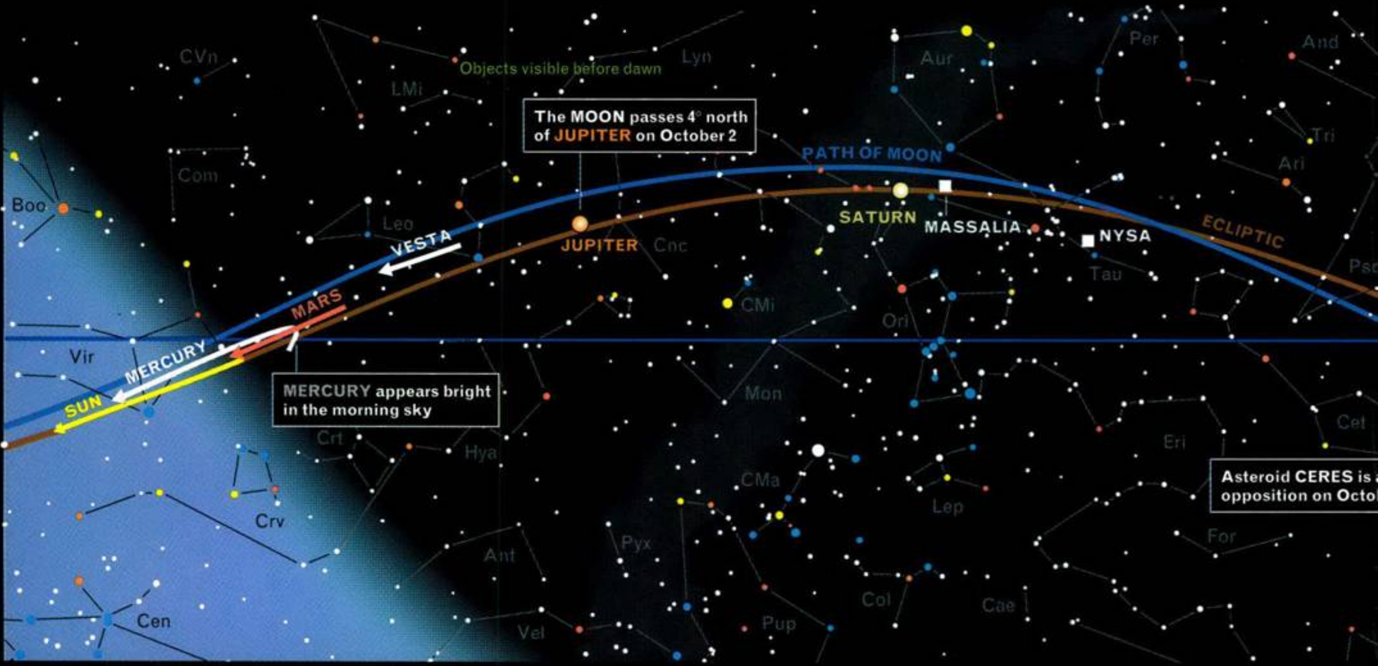
The all-sky map shows how the sky looks at
10 P.M. on October 1
9 P.M. on October 15
7 P.M. on October 31

Planets are shown at midmonth

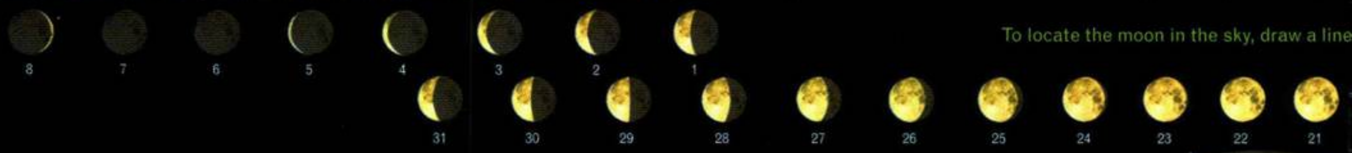
North
South
West
URSA MAJOR
M81
M82
LYNX
Mizar
M51
CAMELOPARDALIS
URSA MINOR
NCP
Polaris
DRACO
BOOTES
CEPHEUS
CASSIOPEIA
PERSEUS
884
869
CORONA BOREALIS
HERCULES
M13
ANDROMEDA
TRIANGULUM
M31
M33
LACERTA
Deneb
CYGNUS
Vega
LYRA
M57
SERPENS CAPUT
PEGASUS
VULPECULA
M27
SAGITTA
OPHIUCHUS
ECLIPTIC
Enif
M15
DELPHINUS
Altair
AQUILA
SERPENS CAUDA
EQUULEUS
M11
SCUTUM
M16
M17
AQUARIUS
URANUS
M22
M20
M8
CAPRICORNUS
SCULPTOR
Fomalhaut
PISCIS AUSTRINUS
MICROSCOPIUM
SAGITTARIUS
CORONA AUSTRALIS
GRUS
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

Path of the Planets

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects



CVn
Objects visible before dawn
Lyn
LMi
Aur
Per
And
The MOON passes 4° north of JUPITER on October 2
Com
PATH OF MOON
Tri
Ari
Boo
Leo
SATURN
MASSALIA
NYSA
ECLIPTIC
VESTA
JUPITER
Cnc
Tau
Psc
MARS
CMi
Ori
Vir
MERCURY
SUN
MERCURY appears bright in the morning sky
Mon
Cet
Crt
Hya
Eri
CMa
Asteroid CERES is at opposition on Octo
Crv
Lep
Pyx
For
Ant
Col
Cae
Cen
Vel
Pup



8
7
6
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1
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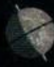
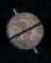
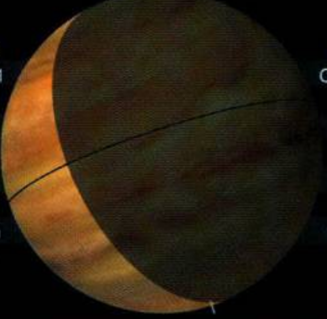
23
22
21

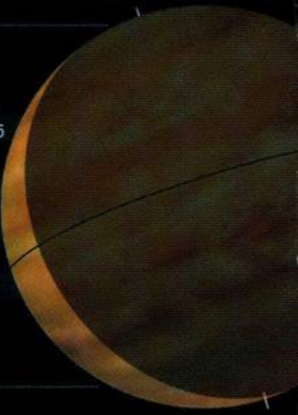
To locate the moon in the sky, draw a line

PLANETS	MERCURY	MERCURY	VENUS	VENUS
Date	October 15	October 31	October 1	October 15
Magnitude	−0.7	−1.0	−4.6	−4.5
Angular Size	6.6''	5.0''	42.8''	53.5''
Illumination	61%	96%	22%	9%
Distance (AU) from Earth	1.017	1.344	0.390	0.312
Distance (AU) from Sun	0.314	0.395	0.727	0.726
Right Ascension (2000.0)	12h16.2m	13h47.6m	14h37.4m	14h41.9m
Declination (2000.0)	0°14'	−9°35'	−22°02'	−23°15'



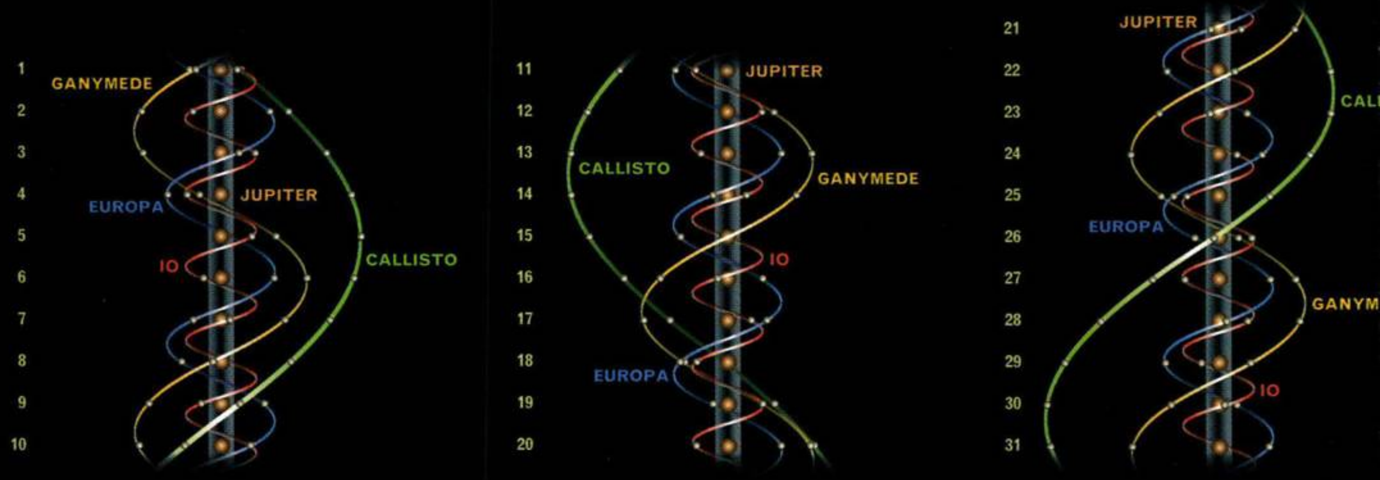




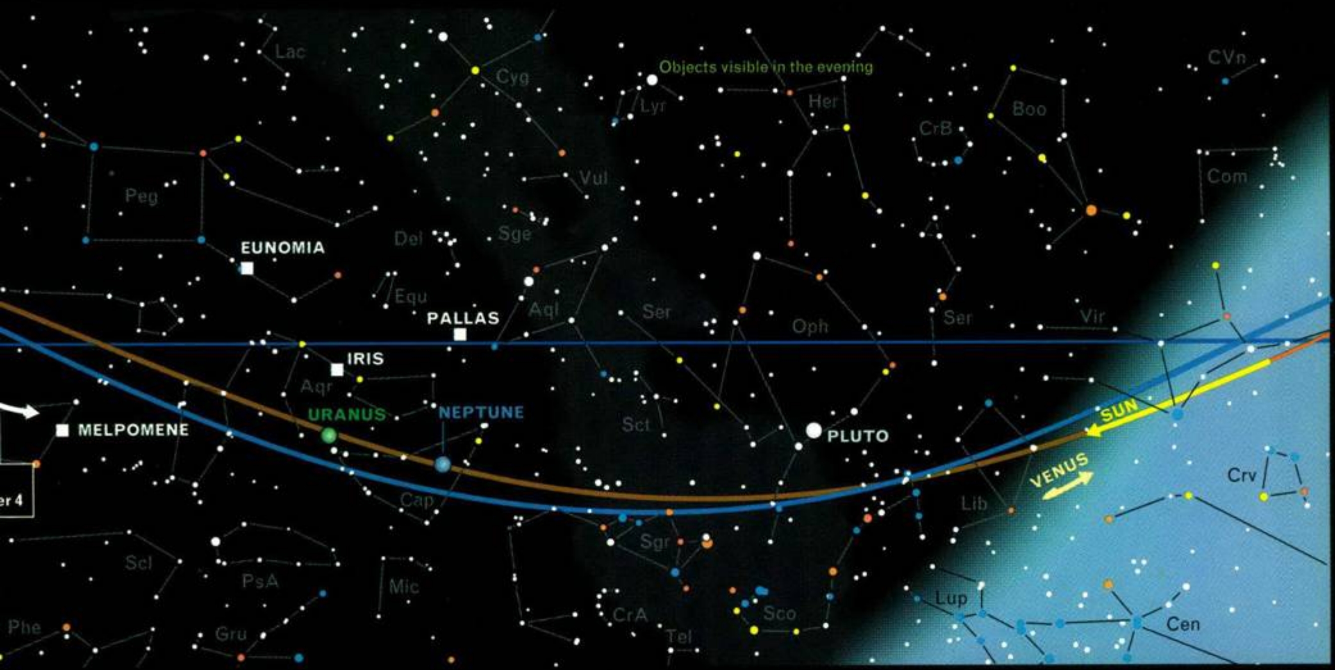


Jupiter's Moons

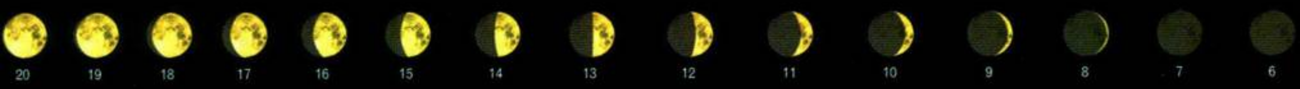
Dots display positions of Galilean satellites at 5 A.M. EDT on date shown. South is at top to match the view in a telescope.



uring the month.


Lac
Cyg
Objects visible in the evening
Lyr
Her
CrB
Boo
CVn
Com
Peg
Vul
Sge
Del
EUNOMIA
Equ
PALLAS
Aql
Ser
Oph
Ser
Vir
IRIS
Aqr
URANUS
NEPTUNE
MELPOMENE
Sct
PLUTO
SUN
VENUS
Crv
er 4
Cap
Lib
Sgr
Scl
PsA
Mic
CrA
Sco
Lup
Cen
Phe
Gru
Tel

rom the phase shown for the day straight up to the curved light-blue line.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19
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16
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6

MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
October 15	October 15	October 15	October 15	October 15	October 15
1.8	−2.0	−0.1	5.8	7.9	13.9
3.7"	35.3"	19.3"	3.6"	2.3"	0.1"
99%	99%	100%	100%	100%	100%
2.546	5.581	8.612	19.440	29.785	31.131
1.663	5.275	9.039	20.009	30.087	30.566
11h59.9m	9h07.5m	5h55.8m	21h50.3m	20h42.3m	17h01.3m
1°11'	17°02'	22°07'	−13°54'	−18°10'	−13°17'

ISTO

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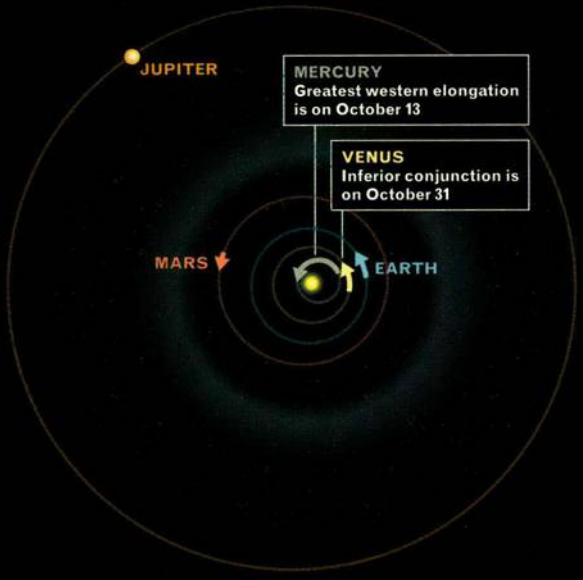
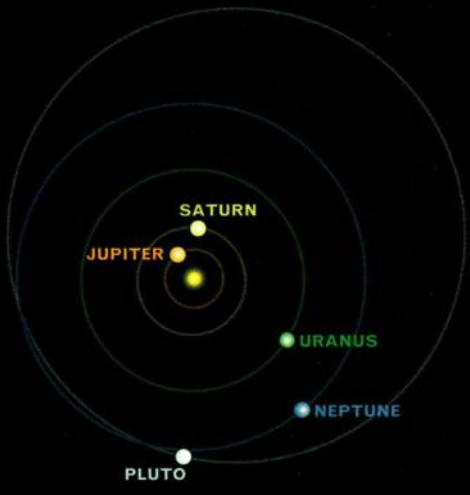
The Planets in Their Orbits

Arrows and dots show planets' positions during the month.


JUPITER
MARS
EARTH

MERCURY
Greatest western elongation is on October 13

VENUS
Inferior conjunction is on October 31


SATURN
JUPITER
URANUS
NEPTUNE
PLUTO

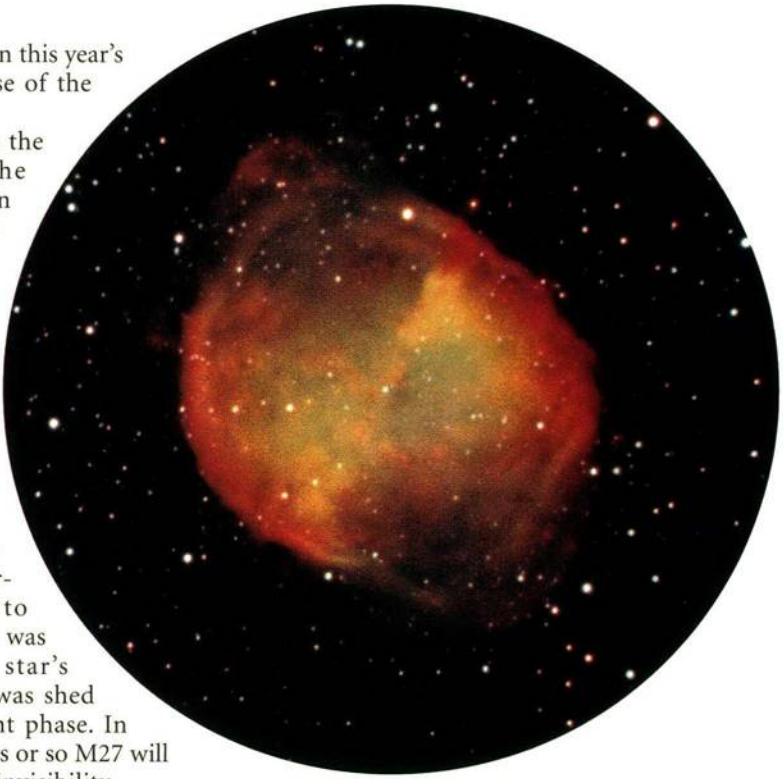
Ghosts in the Galaxy

As some costumed kids approach from up or down the sidewalk on Halloween night you hear one of them whisper excitedly, "Sweet! A telescope!" There are always some bright young minds eager to receive a celestial treat. But since the moon and bright planets are out of view at the end of the month, you may want to target some deep-sky objects that stand out under city lights.

On one side of the sky, aim for the bright star cluster M11 in Scutum; but make sure you give it enough power — 100x or more — to pinpoint some of its individual stars. If you can, use an eyepiece that has long eye relief so that kids with glasses (and especially their parents) don't have to refocus. Another good target that's not too far is the colorful double star Albireo at the foot of the Northern Cross.

Be prepared for questions from the trick-or-treaters, albeit mostly about the cost of your scope. Albireo is about 380 light-years away, and is not a true binary star. The two components travel in different directions. The orange component is about 100 times brighter than the sun. In stark contrast, the stars in M11 are about 5,600 light-years away. In truth, they are giants and if we lived inside that cluster the sky would be filled with bright stars.

On the other side of the sky you can show off the Double Cluster in Perseus, a region packed with stars. Skip across into Cassiopeia for the Owl Cluster (NGC 457). With two very bright stars, this cluster also carries the nickname "E.T."— a timely object given this year's cinematic re-release of the classic movie.



Lift your observing spirits with a nice view of the Dumbbell Nebula. Ken Blankenship and Dennis Batis

A true ghost in the sky is M27, the Dumbbell Nebula in Vulpecula. Even though you can see its patch of light in binoculars, the excited gas cloud is so rarefied that it's emptier than any earthbound laboratory vacuum. Ultraviolet light from the hot central star causes surrounding atoms to fluoresce. This gas was once part of the star's upper layers, but was shed during its red giant phase. In another 10,000 years or so M27 will have diffused into invisibility.

The Coathanger is a group of stars near Sagitta, a delightful spray perfect for binoculars. Even though the Hipparcos satellite finally proved that the stars lie at a wide variety of distances, and are therefore not a true association, it's hard to deny the charm this asterism has cast over the years on skywatchers.

While you are looking at the Coathanger, shift your gaze to the west and look for the eclipsing variable U Sagittae. If you can't see it, you've caught it right in the middle of its eclipse. A faint, larger star totally blocks out the light from the brighter companion every 3 days, 9 hours, and 8 minutes. Its normal brightness is about magnitude 6.5, but over the course of an hour or so it plummets almost 3 magnitudes to a minimum of 9.1. The eclipse lasts only 100 minutes, so it's not trivial to catch it in action. Use the table below to pick a good night. To see predictions for other times check out the AAVSO website: http://www.aavso.org/committees/eb/eb2002.pdf.

The Owl Cluster (NGC 457) always excites newer observers. Michael Stecker

U Sagittae

Light minima occur at the following times:

United States		
Oct. 4	8:30 P.M.	E.D.T.
Oct 14/15	Midnight	E.D.T.
Oct 25	3:30 A.M.	E.D.T.
Europe		
Oct 5	0:30	UT
Oct 10	19:00	UT
Oct 20	22:30	UT

sky Show

During the first week of October you might still glimpse **Venus** before it's hidden by the sun's brilliance. On October 1 Venus sits 10° above the southwestern horizon at sunset, and then dips below the horizon one hour later. At magnitude –4.5, those with a clear view to the southwest should easily find the planet. Each night thereafter, Venus sets approximately two or three minutes earlier until it finally sets with the sun on October 23.

Watch Venus through a telescope during the first week of October, and you'll see a large, slender crescent. On October 1, roughly 20 percent of Venus's disk is illuminated, which shrinks to 10 percent by the end of the second week, when Venus is only visible in a bright sky. Venus reaches inferior conjunction on October 31.

Once Venus dips below the horizon and the sky has darkened, the next planetary targets are an easy catch in binoculars. Invisible to the unaided eye, Uranus and Neptune linger in Aquarius and Capricornus, respectively. Neptune rises first and is the more distant of the two and, consequently, the fainter of the two distant giant planets.

Neptune lies just over 3° east of Rho (ρ) Capricorni, which you can find in the southern sky during the early evening hours. As you scan to the east of Rho Capricorni with binoculars you'll come across the magnitude 5.2 star Upsilon (υ) Capricorni. Slightly farther east of that star lies a magnitude 7.3 star (SAO 163811). Neptune shines at magnitude 7.9. On October 1 the planet and this star appear so close together that they look more like a double star system. However, through a telescope Neptune will show up as a distinct disk, in contrast to the pinpoint image of the star. During October Neptune will move west of the faint star, then halt, and move eastward toward it again, marking the end of its retrograde loop that all outer planets perform around the time of opposition.

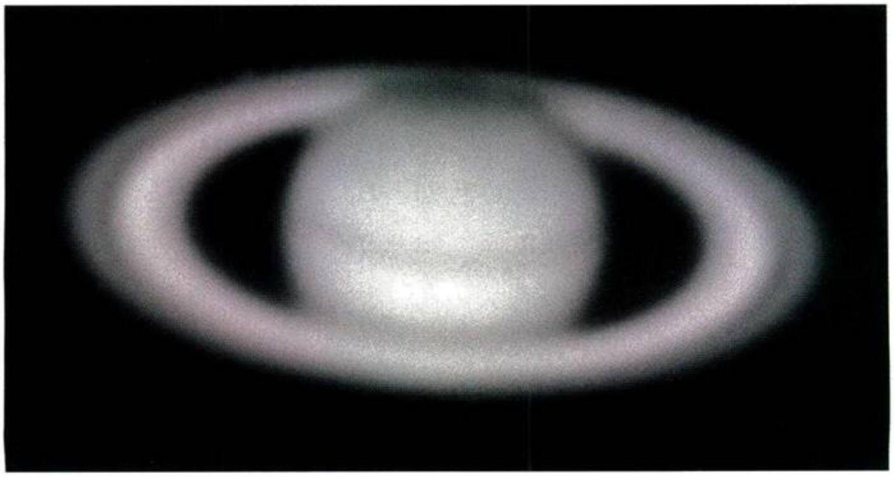
Mercury (upper right) shares the evening sky with a waxing crescent moon. Ed Post

Uranus is easier to find; it shines at magnitude 5.8 and lies at the eastern end of Capricornus. Look for a dim greenish-colored object 2.5° north-northeast of the magnitude 2.8 star Delta (δ) Capricorni. Near this same position lies the magnitude 5.1 star Mu (μ) Capricorni, which is almost as bright as Uranus. The seventh planet moves farther away from Mu Cap each night, and you can easily track its motion with binoculars. From really dark sites you might glimpse the planet with the unaided eye. Uranus stands 5° north of the waxing moon on the night of October 15.

Saturn rises in the late evening just before midnight during October, and it glows at a respectable magnitude 0. The Ringed Planet lies between the well-known constellations Taurus and Gemini, and spends the entire month in a small northern section of Orion. By midnight, Saturn is well clear of the western horizon. Binoculars will reveal the planet sitting nearly 4° west-southwest of the open star cluster M35.

Saturn's path against the stars will slow to a halt October 11. Later it begins its retrograde path as we observers on Earth begin to overtake Saturn. In two months Saturn will reach opposition, when it stands directly opposite the sun and shines a half-magnitude brighter. However, this month the rings open to their widest since they first began opening following 1995's ring crossing. The southern face of the rings has been opening ever since.

The rings of Saturn, visible in any small telescope, span 44" along the major axis and nearly 20" across the minor axis. Saturn's disk spans 19". Good observing conditions should reveal the rings' Cassini Division now that they are so open to view. Small telescopes will also show Saturn's largest moon Titan, which shines at magnitude 8.3. Titan lies due north of Saturn on October 8 and 24, and due south on October 16.



Saturn opens its rings* — *an ideal time to observe their numerous divisions. Donald C. Parker

Jupiter rises after midnight and is

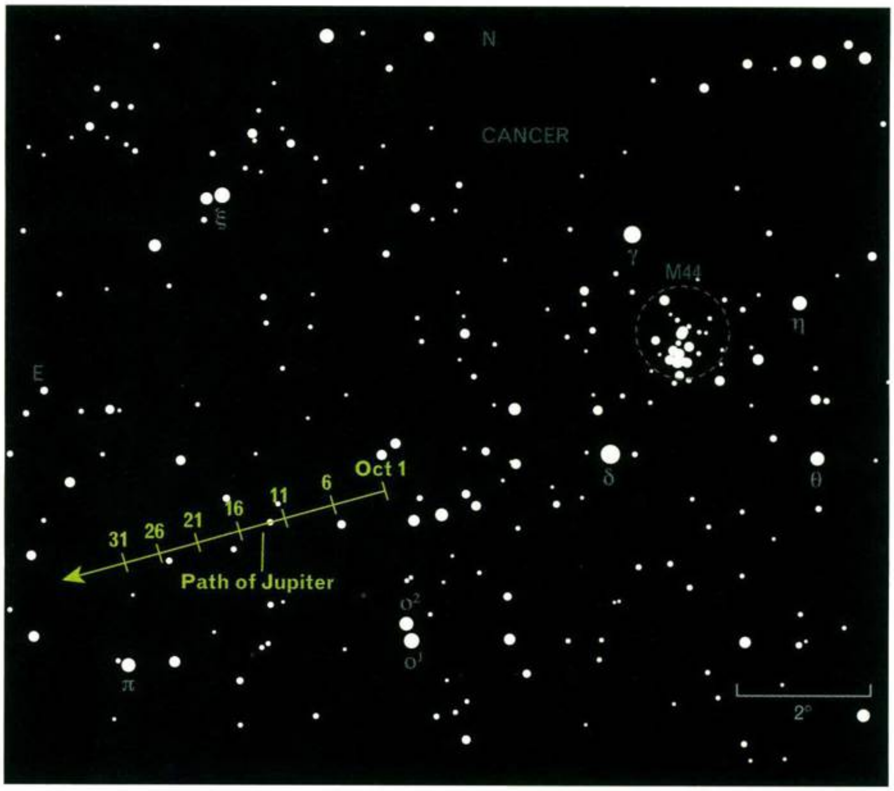
most observable during the early morning hours. By the end of the month, the combination of Daylight Savings Time and the early rising of Jupiter make the planet a good object to view in the later-evening hours. The huge gas giant lies east-southeast of the Beehive Cluster (M44) in Cancer the Crab. Jupiter shines at magnitude –2.0, which far outshines any star in Cancer.

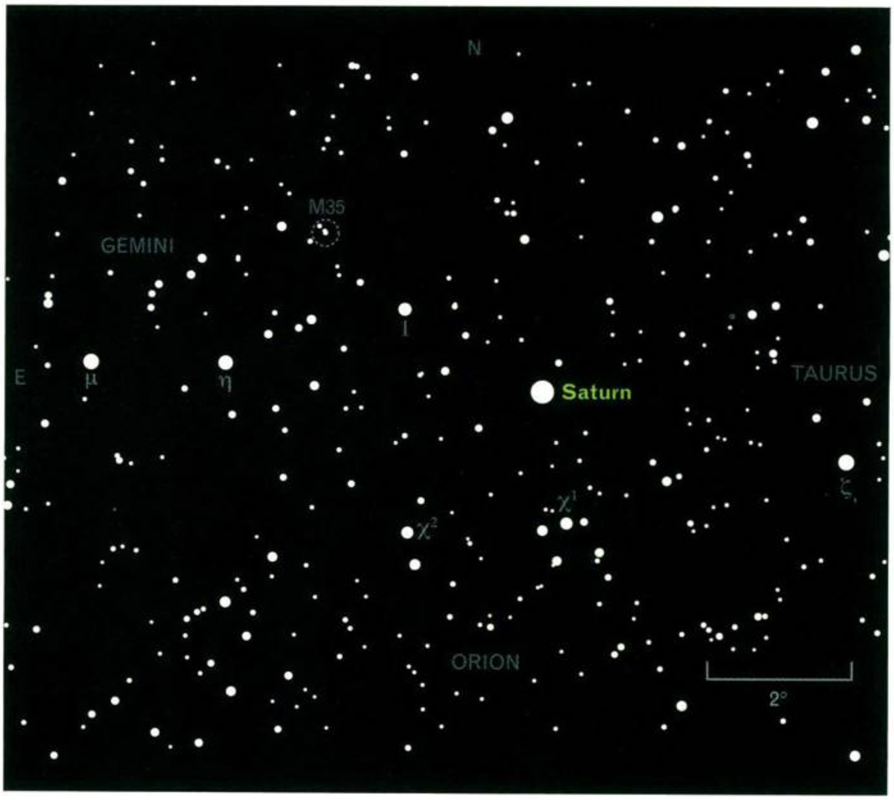
The apparent size of Jupiter's disk grows by 3" this month, starting out at 34" on October 1. Views through a telescope easily show the planet's most obvious features. First, you'll notice the two dark equatorial belts; these two prominent features carry many smaller plumes of clouds that regularly track across the face of the planet. Jupiter's extremely fast rotation carries these features across the disk within just one evening. Six-inch and larger scopes will reveal much finer detail, such as the much more subtle belts that lie parallel to the pair of dark, distinct equatorial belts.

Jupiter's four major moons — Io, Europa, Ganymede and Callisto — are all visible in any telescope, and even in carefully mounted binoculars. Occasionally, one of these moons will pass in front of the planet. The shadow of a moon transiting the planet is easy to see, and it's enjoyable to compare your timing of such transits with the predicted times in handbooks.

Mars reappears in the dawn sky following its August conjunction with the sun. The Red Planet lies in Virgo the Virgin, and during the month it swings eastward where it stands near Porrima, or Gamma (γ) Virginis. On October 31 Mars stands three moon-widths southwest of Porrima, where it shines at magnitude 1.8. The planet is beginning its slow trek toward its late-summer perihelic (closest to the sun) opposition in 2003.

Mercury appears in the morning sky, and stands less than 3° east of Mars on October 11. It's brighter than the Red Planet and will continue to brighten until October 8, when it graces observers with a respectable glow at magnitude of 0.5. Mercury reaches magnitude –0.5 a week later when, on October 13, it reaches its greatest elongation west (13°) of the sun.





sky Show

Meteors and Moons

October Meteors

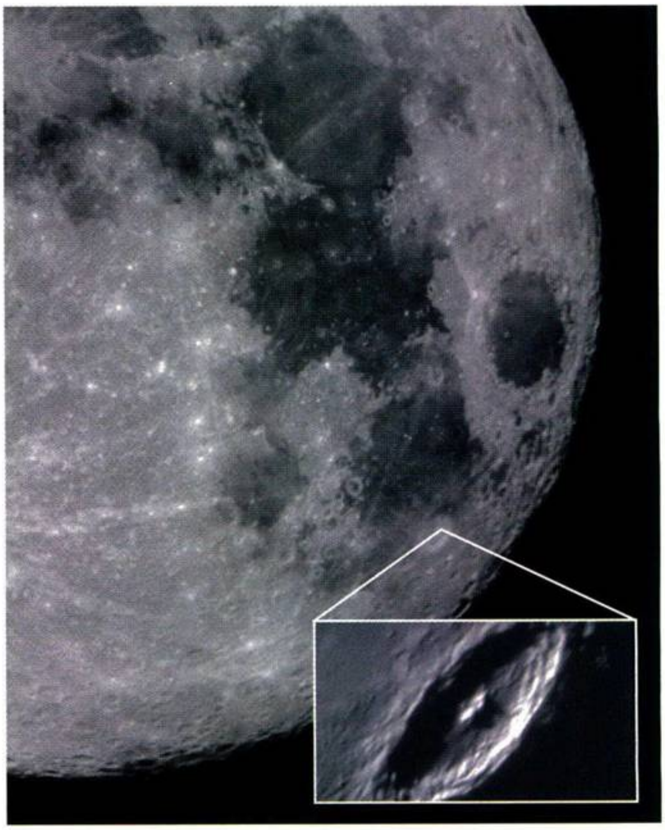
The well-known Orionid meteor shower is strongly affected by the moon this year, with the full moon occurring on October 21, the predicted night for the shower's peak.

Some Draconids should streak across early October's sky. The parent comet of this shower, Giacobini-Zinner (21P), passed through perihelion in 1998. Observers reported brief but strong activity in 1998 and 1999. The highest potential for major activity occurs on the evening of October 8 in the United States. Observers around the Northern Hemisphere should be on alert between 2 P.M. UT on October 8 through 7 A.M. UT on October 9.

A Leg Up on Langrenus

The large lunar crater Langrenus is well placed for viewing this month. Situated at the eastern side of Mare Fecunditatis and south of Mare Crisium, the crater first comes into view soon after the new moon. Libration — the moon's gentle back and forth rocking that over a period of time allows us to see more than 50 percent of the lunar surface — places the entire eastern limb of the moon toward us in the days following October 6's new moon. This positions Mare Crisium, Mare Fecunditatis, and the crater Langrenus all as better observing targets.

Langrenus is an 82-mile (132-kilometer) wide crater with fine-terraced walls. A central mountain peak rises about 0.5 miles (0.8 km) above the crater floor. The optimal time to view Langrenus with favorable libration will be for a few days after October 9, when the sun rises over the crater. Look how much farther east of Langrenus you can see, where a chain of substantial craters will have a unique viewing angle this month. Look for the pair of similarly sized small craters, Langrenus A and Kapteyn, just due east of Langrenus. Farther east still is the 48-mile (77-km) wide crater La Pérouse, which is bordered to its north by the ancient walled plain Kästner, and to its southeast by the 58-mile (93-km) wide crater Ansgarius.



The stunning lunar crater Langrenus is an easy observing target once you're in the vicinity of Mare Fecunditatis (Sea of Fertility) and Mare Crisium (Sea of Crises).

Christophe Bithune

Shortly after the full moon, on October 21, the crater Langrenus presents a very different appearance than the one seen in early October. This time the setting sun will illuminate the terraced eastern wall, and you can track the shadow of the central mountain peak as it stretches across the lava-filled crater floor.

Galilean Treats

Jupiter's return to the evening sky marks a return to tracking the rare occultations, eclipses, and transits involving the outer Galilean moon Callisto. During each 12-year orbit of Jupiter around the sun, only two series of eclipses involving Callisto occur.

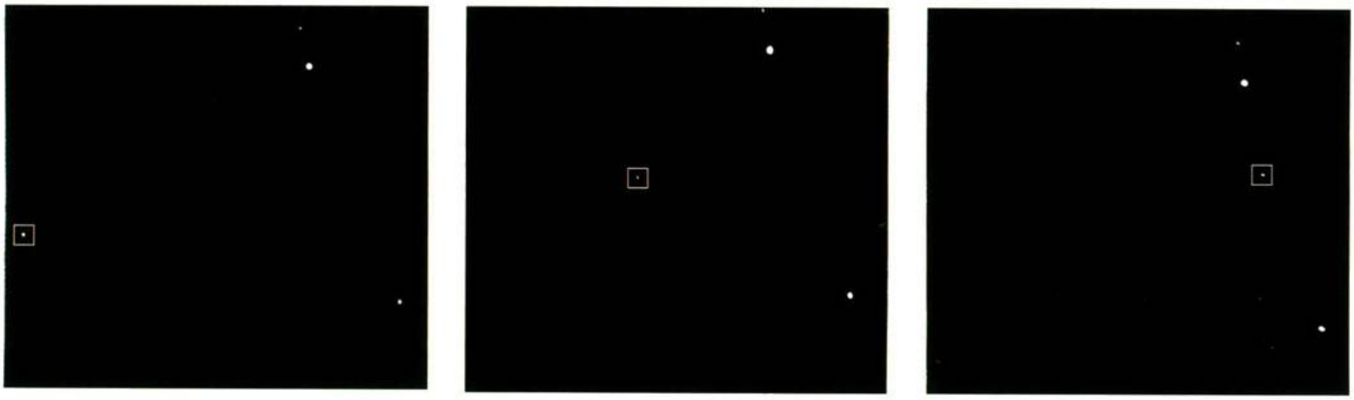
The current series began in late 2001 and continues until September 2004, a time frame in which only 66 eclipses will occur. The events listed in the adjacent table are given in Universal Time (Greenwich Mean Time) and Eastern Daylight Time.

Events that occur on either side of midnight are shown twice*, since the date changes for observers in Europe or the United States of America. Tr = transit; I = Ingress; E = Egress; Oc = occultation; Sh = shadow transit; Ec = eclipse; D = disappearance; R= reappearance.

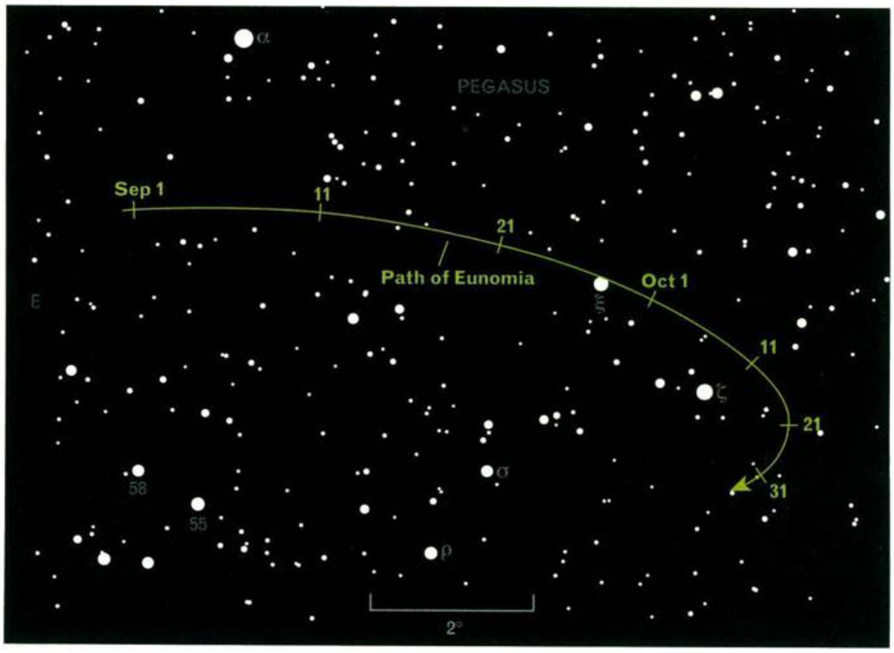
Observing these jovian satellites takes patience, but it's well worth the reward of seeing them do their orbital dance.

Catch Callisto

UT	EDT	
Oct 9		
5:17	12:17 A.M.	IV.Sh.I.
9:51	4:51 A.M.	IV.Sh.E.
15:53	10:53 A.M.	IV.Tr.I.
20:36	3:36 P.M.	IV.Tr.E.
Oct 17		
12:45	7:45 A.M.	IV.Ec.D.
17:27	12:27 P.M.	IV.Ec.R.
19:11	7:11 A.M.	*IV.Oc.D.
Oct 18		
00:11 A.M.		IV.Oc.D.
5:03	00:03 A.M.	IV.Oc.R.
Oct 25		
23:15	6:15 P.M.	IV.Sh.I.
	11:52 P.M.	*IV.Sh.E.
Oct 26		
3:52		IV.Sh.E.
10:49	6:49 A.M.	IV.Tr.I.
15:35	11:35 A.M.	IV.Tr.E.



Above: The asteroid Ceres slowly passes between 103 and 104 Aquarii. *Astronomy* collection



Vermin on the Winged Horse

How times have changed. It took seven years from 1801 to 1807 to catch the first four big rocks of the asteroid belt. By the early 20th century discoveries were so numerous that asteroids were nicknamed the "vermin of the skies." More recently, they've gained respect thanks to a few big space rocks zooming uncomfortably close to our planet.

This month there are three asteroids worthy of pursuit from the backyard in even the smallest of scopes. Eunomia, the 15th ever discovered, is a decent-sized chunk of real estate about 170 miles (270 km) across. Still, this is roughly half the size of 2 Pallas and 4 Vesta. Eunomia glows at about magnitude 8.5 on the back of Pegasus, near the star Zeta (ζ) Peg and not far from Alpha (α) Peg, which together form the "lower right" of the Great Square of Pegasus. In the early part of the evening, the square is tilted into a diamond shape, with α on the right corner. Because this part of the sky is relatively sparse, there's not much chance of confusion when you have a look at 50x or 100x.

Still bright are 7 Iris and 1 Ceres. Iris is to the west of the "water jar" asterism in Aquarius while Ceres is lying in front of the stars of Cetus the Whale. Ceres is almost a full magnitude brighter than Eunomia, which will make it an easy target. In next month's Sky Show, we'll take a closer look at the number 1 asteroid. To retrieve close-up star charts of their paths, check out the website of the British Astronomical Association at http: //yan.open.ac.uk/~ajh47/arps.html.

Comet RX14 LINEAR

Most amateurs want to see a really nice comet every couple of months. Chances are, though, that our comet luck has run out, and the only one bright enough for observation is RX14. But even then you'll need a dark, moon-free sky (the new moon on October 6 will help) and a fantastic observing site. Comets are always a bit unpredictable, and at 12th magnitude, RX14's diffuse nature will make this a real challenge in an 8-inch telescope.

Secure the right field, then move the power up to about 100x. Any lower and the sky brightness has a chance to obscure the comet's faint glow. Slowly rock the scope back and forth so you can trick your brain into picking up its motion across the field. If that doesn't work, try surrounding your head and eyepiece with a dark hood. Blocking out stray light can be very important at these low light levels.

Over the next couple of months, astronomers expect RX14 LINEAR to crest near 10th magnitude brightness — the faint end of the Messier objects. ■

Martin Ratcliffe is President of the International Planetarium Society. Alister Ling is a meteorologist for Environment Canada.

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Ultra Wide 6.7	200
Ultra Wide 8.8	240
Ultra Wide 14	300

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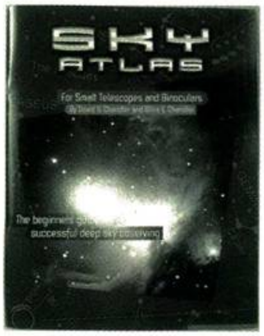
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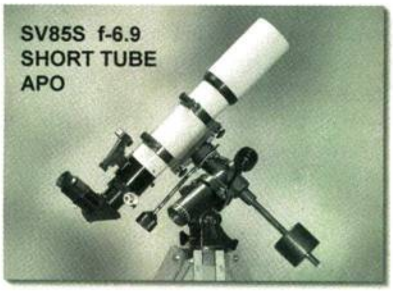
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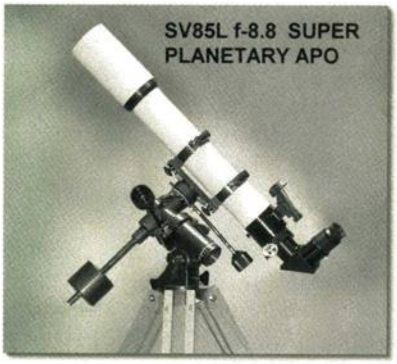
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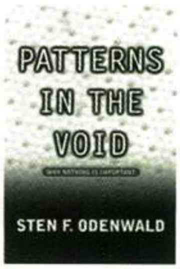
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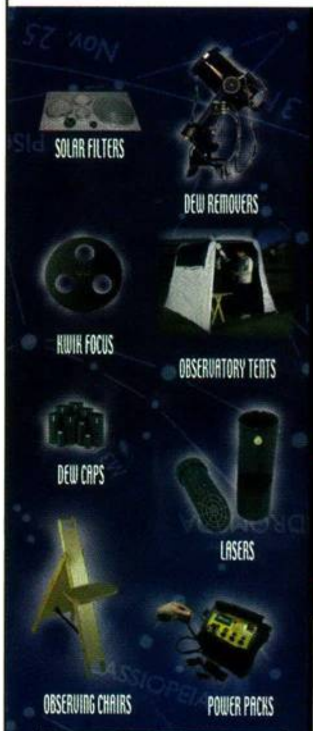
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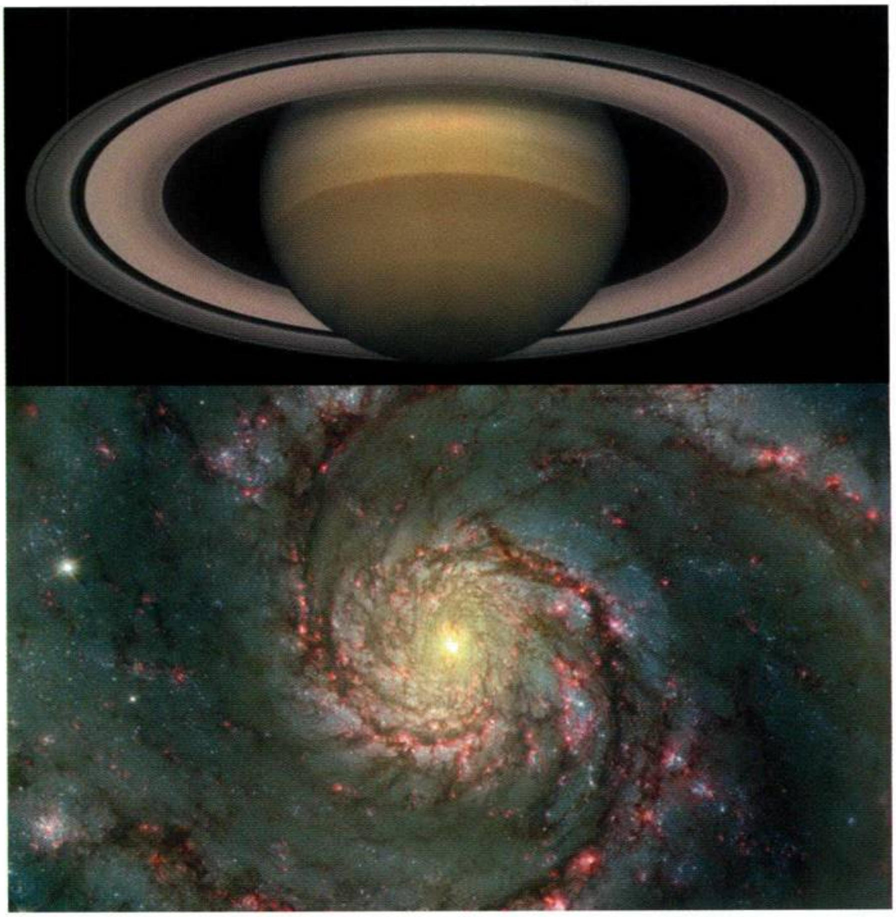
Hubble Images of the Solar System, Equipment Advice, Early Seasons

Every object in our solar system is so much closer than the stars, nebulae, and galaxies imaged in such detail by the Hubble Space Telescope. So why can't Hubble give us extreme close-up images of, say, Mars, Saturn, or Pluto? — ***Shawn Person, Lyons, Colorado***

Looks can be deceiving. When it comes to taking sharp pictures of a celestial object, three factors play key roles: the quality of the optical system that collects the light, the resolution of the camera taking the image, and the steadiness of the photographic setup.

Hubble provides the same optical system and pointing stability regardless of the object it's viewing. So, if we consider just one of Hubble's cameras, all the factors affecting sharpness will be the same and the images will have similar resolutions. (That doesn't take into account that both of Hubble's visible-light cameras — the venerable Wide Field Planetary Camera 2 and the new Advanced Camera for Surveys — have high-resolution modes that provide crisper images of small regions.)

But when it comes to the *apparent* sharpness of an image made with Hubble, the object's apparent size plays a big role. The larger an object appears in the sky, the sharper its image will seem. The same holds true in photography on Earth — a picture of an elephant taken from 50 feet looks more detailed than a picture of an ant taken from 10 feet. Solar system objects just happen to be the ants of the celestial zoo.



Saturn is less detailed than M51 because it appears smaller in the sky. NASA/STScI

Let's look at an example. In our solar system, Saturn has a diameter of 74,900 miles while its rings span 169,000 miles. When the planet reaches opposition this December, and thus lies closest to Earth, it will be 748.5 million miles away. Dividing diameter by distance gives angular size. So at opposition, Saturn will appear 21" across and the ring system will spread 47", or just 0.013°.

Compare that with the Whirlpool Galaxy (M51) in Canes Venatici. It lies about 31 million light-years from Earth — roughly 250 billion times farther than Saturn. Yet it spans 75,000 light-years, some 2.6 trillion times the ring diameter of Saturn. That gives it an apparent size of 8.2' (0.14°), a little more than 10 times that of Saturn. So if you view Hubble images of M51 and Saturn at the same size, the galaxy appears to have significantly more detail. Because the apparent size of Saturn's rings rivals Jupiter and dwarfs Mars and Pluto, Saturn is about as good as Hubble can do in the solar system. — *Richard Talcott, senior editor*

CONTACT INFO

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I am very interested in observing planets, globular clusters, and planetary nebulae. What type of telescope would be suitable for this kind of observing, what aperture would you recommend, and what type of mount would be advised for a beginner? — *John Gibson*

I usually advise the largest aperture possible when it comes to resolving anything celestial, be it lunar, planetary, or deep sky. Light is a telescope's raw commodity. The bigger its main objective lens or mirror, the greater the resolution. So buy the largest scope you can afford. Quite simply, it will reveal more sights.

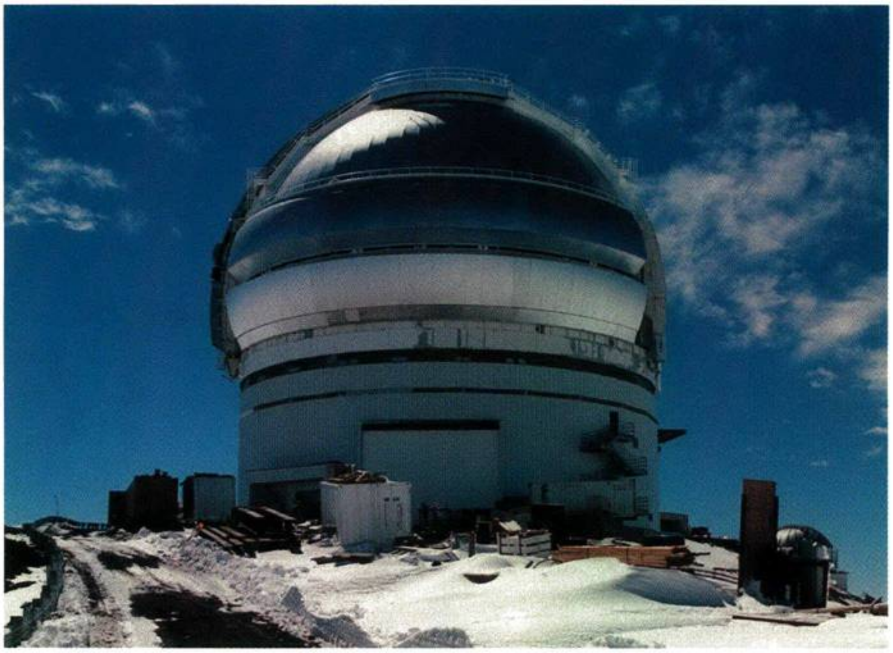
Still, many aficionados hold that some of the best planetary scopes are refractors. Reflecting telescopes rely on a secondary mirror to redirect light into the eyepiece. A secondary mirror, along with its housing or support vanes, lies along the path of incoming light. This "secondary obstruction" has a noticeable effect on how sharp a focused image appears. A secondary also scatters light, which adversely affects contrast.

Refractors avoid all this. Their unobstructed optics often yield better-contrast images that come to a snappier focus. The downside is that larger refractors are expensive. An 8-inch reflector goes for less than $600. A similar-sized refractor runs several thousand dollars.

Some observers try to mimic a refractor's performance with a reflector by slipping an "aperture mask" over the scope's opening. This mask has an offset hole three to four inches in diameter that lets light into the scope without hitting the secondary. Often enough, though, a well-tuned reflector does a more-than-adequate job in revealing many details on the moon and planets. Slip off the aperture mask to view fainter deep-sky objects.

With regard to a mount, unless you plan on doing long-exposure photography, there's really no reason to get anything more complex than a solid alt-azimuth or Dobsonian mount. These "plug and play" mounts don't require any alignment, as an equatorial mount does. — *John Shibley, contributing editor*

Bigger scopes usually give better views of objects like the Owl Nebula (M97). John Chumack



Winter would eventually arrive in autumn if our calendar didn't compensate. NOAO/AURA/NSF

If the equinoxes occur slightly earlier every year due to precession, why do the seasons not fall noticeably earlier in the year after a long period of time? — *Graeme Clement, North Perth, Western Australia*

We can thank the people who devised our calendar. The time it takes Earth to revolve around the sun depends on what you refer the motion to. If you measure Earth's revolution with respect to the stars, called a sidereal year, it takes our planet 365.2564 days to go around once. If you measure the motion with respect to the vernal equinox — the point on the sky where the sun crosses the celestial equator moving from south to north, which occurs on the first day of spring — it takes 365.242199 days. This so-called tropical year ends up about 20 minutes shorter than a sidereal year, thanks to the precession of the equinoxes.

Calendar-makers chose to align the calendar with the seasons, so it is based on the tropical year. Unfortunately, that 0.242199 of a day makes it impossible to keep the calendar perfect. The first successful attempt to bring some order came with Julius Caesar, who in 46 B.C. instituted a calendar reform that decreed a leap year every fourth year. That gives a year averaging 365.25 days, just 11 minutes and 14 seconds longer than a tropical year. Not a big discrepancy, but those minutes added up.

By 1582, 13 days had accumulated and the vernal equinox came on March 11. To prevent further slippage, Pope Gregory XIII dropped ten days from the calendar by proclaiming the day after October 4, 1582, to be October 15. He also modified the rule for leap years so that years divisible evenly by 100 would not have an extra day unless they were also divisible by 400. The Gregorian calendar matches the tropical year to within a day about every 3,300 years.

But there is one noticeable effect that arises from the different lengths of the sidereal and tropical years. Instead of the seasons falling earlier as the centuries pass, it's the stars that get out of whack. Over time, the stars we associate with a given season will change. Orion, a winter constellation now, will be gracing the summer sky by around 15,000 A.D., when Earth will be about halfway through its 26,000-year-long precessional cycle. Likewise, Sagittarius will then be gleaming down on us during the frigid winter months. — *R. T.* ▣

Refractor Road Test

Choosing your first telescope can be as daunting as settling on your first car. Astronomy *takes four small refractors out for a spin.*

By Phil Harrington

Deciding which telescope is best for new stargazers is a favorite activity at astronomy clubs, in online astronomy chat rooms and discussion groups, and at star parties around the world. One reason for this debate is that no one answer will suit everybody. So many considerations must be made before charging ahead and purchasing that first telescope. How much money do you have to spend? Is portability important? What types of sky objects interest you the most?

It's this last question that often tips the balance for neophytes who are trying to choose between the two most popular telescope types: reflectors and refractors. In general, reflectors offer more inches of aperture for the buck, which means these scopes capture more light and resolve fainter objects. But there's a tradeoff: The signature mirrors inside reflectors can wash out some of the contrast in images because they stand directly in the light's path to the eyepiece. So if you're interested in mostly bright quarry, such as the moon, the importance of image quality may eclipse the need for brightness, and it's the refractors' time to shine. Here I review four refractors with apertures between 2.4 and 4 inches (60mm to 100mm), the likes of which have given many lifelong astronomers, including yours truly, their first close-up views of the moon, planets, and brighter deep-sky objects.

All telescope photos provided by manufacturers.

Background images: ESO

SWIFT

Small refractors have gotten a bad rap in recent years, probably because of their distant cousins that are sold in department stores. You know the kind: those toylike telescopes with their nanoscale eyepieces and flimsy mounts. All four of the instruments here are well above that level, and while they do not have Go-to computerized control, they do provide for some good, old-fashioned stargazing.

In an effort to evaluate some of the small refractors on the market today, I gathered a few instruments from their manufacturers: the Celestron Firstscope 80EQ, the Orion AstroView 90, the Stellarvue 80/9D, and the Swift Model 865. All come with extendable tripods and light-duty, manually operated German equatorial mounts, except for the Stellarvue, which was supplied for this test without a mounting. Each mount is similarly equipped with manual slow-motion controls on the right ascension and declination axes, small setting circles, and locking latitude-adjustment screws and reference scales.

Each telescope also comes with several accessories. The Orion and Swift both include 6x30 finder scopes, while the Celestron comes with a red dot "unity finder," which projects a red dot against a reflective window. This lets the observer see both the red dot as well as the sky beyond, allowing him or her to aim the telescope at a selected target. Unlike the 6x30 finders, unity finders do not magnify the view nor do they make dim stars appear brighter. In fact, the Celestron red-dot finder has a reddish coating on its window that reduces star brightness by about one-half magnitude. Finally, the Stellarvue does not include a finder, but one can be purchased "à la carte."

Of the two 6x30 finder scopes, Orion's is superior. Not only does it mount to the telescope with an easier-to-adjust mounting bracket; it also yields brighter images. I checked both finders and found that they each produce the same 5mm exit pupil, yet the Swift struck me as dimmer.

In addition to their finders, each telescope comes with a 1¼" rack-and-pinion focuser, a 90° star diagonal, and one or two eyepieces, again, except for the Stellarvue, explained below. The Celestron comes with 10mm and 20mm MA eyepieces (yielding magnifications of 90x and 45x, respectively); the Orion includes 10mm and 25mm Kellner eyepieces (91x and 36x, respectively), while the Swift includes a 25mm Kellner eyepiece (40x). The Swift has the best eyepiece of the bunch in terms of overall optical quality, but be aware that you'll probably need to add another in the 9mm to 10mm range for acceptable views of the planets.

As mentioned earlier, the Stellarvue is a beast of a different sort. Unlike the others, which are aimed squarely at new stargazers, it is a bit more upscale, both in terms of optical and mechanical performance as well as in the observing experience expected of its user. The base unit includes a very smooth 2-inch focuser, an adapter for 1¼" eyepieces, a 1¼" 90° star diagonal, a pair of tube mounting rings, and a red-dot unity finder. The eyepiece adapter is also threaded to accept T-adapters, enabling owners to attach single-lens reflex camera bodies directly for photography. Optional accessories sold by Stellarvue include an imported German equatorial mount, a padded carrying case, a sky atlas, and several other eyepieces and star diagonals. Several of these items, including 9mm and 25mm Plössl eyepieces, are packaged as the "80/9D Complete System," which sells for about $250 more than the à la carte telescope. Because of these two different versions, beginners should be careful to order the right setup, just so they know exactly what they will be receiving in return. If you decide that the Stellarvue is for you, I would recommend getting the 80/9D Complete System unless you already have a mounting for the telescope. For testing this scope, however, I used my own star diagonal and mounting.

Mechanics

Each of the telescopes includes a nicely painted steel tube. All are a glossy white except for the Celestron, which is their trademark black. The finish was excellent on all.

At the front end of each telescope, the achromatic objective lens is held in place with a non-adjustable lens cell. The Orion and Celestron objective cells were made of plastic, pressed together to hold everything in place, while the Swift and Stellarvue scopes used metal cells. All held their lenses properly, except for the Swift. Its locking ring was tightened down so hard that it actually distorted the objective lens elements. As a result of the pinched optics, images did not focus as well as they might were the cell's locking ring tightened properly. Although I would not recommend this procedure for anyone not intimately familiar with the operation, I was able to correct the problem by loosening the cell's lock ring enough to take the pressure off the elements. Once done, image quality improved noticeably, as mentioned below.

Each of the telescopes comes with a rack-and-pinion focuser to accept standard 1¼" eyepieces. The Stellarvue's 2" focuser,

which includes a 1¼" adapter as standard, was the smoothest, although all worked pretty well. The Stellarvue's two oversized knobs have a very nice ergonomic feel to them, making fine adjustment a snap.

The Swift, Celestron, and Orion refractors come on German equatorial mounts and adjustable aluminum tripods. The identical Celestron and Orion mounts, known as the Celestron CG-3 and the Orion EQ-2, respectively, are the sturdiest. Even though the Orion weighs about 1.5 pounds more than the Celestron, the mount is still able to support it steadily enough for good observations. Admittedly, some shaking did occur when attempting to focus the telescopes, but that's almost inevitable with mounts like these. The manual slow-motion controls used to move the telescope in right ascension and declination when zeroing in on and tracking an object worked very smoothly in both cases.

I was disappointed with the Swift mount. Unlike the others, which locked down securely when I tightened their screws, the Swift mount's polar axis refused to tighten adequately after I tilted the mount at an angle matching my latitude. As a result, the telescope mount shifted unexpectedly when the instrument was swung from object to object across the sky.

Each telescope was shipped to me directly from its respective company and outfitted with the standard equipment previously mentioned. Assembly went quickly and without incident. The instructions left a little to be desired, however, possibly causing a beginner some grief when assembling the instruments. The Orion had the best instructions, in my opinion, followed closely by the Celestron and the Stellarvue. The Swift manual lacked clear illustrations and would probably conspire to only confuse a new stargazer.

Optics

All of the refractors were tested side by side from my backyard on suburban Long Island over several nights. From my observing location, the faintest star I can see by eye alone is usually between magnitude 4.5 and 5, which is probably typical for a majority of *Astronomy* readers and potential consumers. As these tests were conducted last winter, I had a choice of several of the sky's finest showpieces as targets.

First, I turned each of the telescopes toward Saturn. Using my own 10mm eyepiece in each, I was able to detect Cassini's division, the dark band between the two bright outer rings, as well as the planet's equatorial zone in all four telescopes. The Stellarvue produced the sharpest view, with Cassini's division appearing as a pencil-thin line separating the A and B rings. The far more subtle Crepe, or C, ring was silhouetted against the planet's bright disk through the Stellarvue. I could also make out the C Ring through the Celestron and Orion scopes, although not as clearly. It was clear using the Swift only after I loosened the objective lock ring.

Jupiter showed a good amount of cloud structure through all four telescopes, with the north and south equatorial belts readily apparent in each. The Stellarvue delivered the best image, highlighting the clouds with several subtle irregularities that remained invisible through the others. Part of this improvement is attributable to the four light baffles inside the Stellarvue tube, which help boost image contrast by blocking stray light. Jupiter certainly improved through the Swift after the pinching problem was eliminated, though it still showed a bit less cloud detail than the Stellarvue. Neither the Orion nor Celestron showed as much contrast as the others.

My first deep-sky target was M42, the Orion Nebula, which I viewed initially through a 25mm Plössl eyepiece. Once again, the Stellarvue showed the best image contrast, although the Orion's larger aperture was used to good advantage here in producing the brightest image and showing a few subtle extensions of the nebula that went unseen through the others. The Swift's 90mm aperture also produced a bright image, though it did not reveal all of the faint tendrils visible through the Orion.

Switching to my own 7mm Pentax XL eyepiece, I zeroed in on the heart of the nebula — the Trapezium, a quadruple star. All four telescopes had no trouble whatsoever in resolving the Trapezium, although once again, the Stellarvue's optics generated the sharpest star images of the bunch.

Rigel is an excellent test star for small refractors. How a scope resolves its faint companion star, Rigel B, can reveal optical defects such as flaring, and Rigel's own brightness makes clear at a glance how well the scope copes with the Achilles' heel of all telescopes — chromatic aberration. Chromatic aberration causes haloes to appear around images because the scope's main lens separates incoming starlight into its component colors and bends each color at a different angle, so each arrives at a different focal point. While this distortion can never be completely eliminated, these four scopes have a second, corrective, lens nested with the main lens. They all passed the resolution test by showing Rigel B next to its brilliant

Celestron Firstscope 80-EQ

Celestron International
2835 Columbia Street, Torrance,
CA 90503
Phone: (310) 328–9560
www.celestron.com

- Aperture: 80mm
- Focal length: 900mm
- Focal ratio: 11
- Weight: 24 pounds
- Features: 10mm MA eyepiece, 20mm MA eyepiece, 90° star diagonal, red dot finder, German equatorial mount, tripod
- Typical Retail Price: $270

Orion Astro View 90

Orion AstroView 90
Orion Telescopes and Binoculars
P.O. Box 1815, Santa Cruz, CA 95061
Phone: (800) 447–1001
www.telescope.com

- Aperture: 90mm
- Focal length: 910mm
- Focal ratio: 10
- Weight: 24 pounds
- Features: 10mm and 25mm Kellner eyepieces, 90° star diagonal, 6x30 finder scope, German equatorial mount, tripod, adapter for camera attachment
- Typical Retail Price: $300

Swift Model 865

Swift Instruments, Inc.
952 Dorchester Ave., Boston,
MA 02125
Phone: (800) 446–1116
www.swift-optics.com

- Aperture: 90mm
- Focal length: 1,000mm
- Focal ratio: 11.1
- Weight of optical tube assembly only: 30.8 pounds (11 kg)
- Features: 25mm Kellner eyepiece, 90° star diagonal, 6x30 finder scope, German equatorial mount, tripod
- Typical Retail Price: $625

Stellarvue 80/9D

Stellarvue
P.O. Box 7515, Auburn,
CA 95604
Phone: (530) 823–7796
www.stellarvue.com

- Aperture: 78mm
- Focal length: 750mm
- Focal ratio: 9.6
- Weight of optical tube assembly only: 5.5 pounds (3 kg)
- Features: red-dot finder, mounting rings, large focus knobs, 90° star diagonal, adapter for eyepieces, focuser
- Typical Retail Price: $450

parent star; but unfortunately, all the scopes also revealed a good amount of chromatic aberration. The Stellarvue showed the least, with no sign of flaring or internal reflections caused by straying star light, while the Orion, though still acceptable, showed the most. Flares around Rigel were seen through the Swift before the pinched optics were corrected. I also saw some minor flaring through the Celestron, indicating its objective was probably being pinched slightly in its cell.

Finally, I put each scope through the star test, which compares two views of a single bright star — how it looks when the focus knob is turned by equal amounts to the left and right of focus. In an ideal refractor, both images should look like identical patterns of concentric, evenly bright rings. If they disagree, then the culprit might be turbulence in the atmosphere, or worse, an optical defect. It's very important that a telescope be properly cooled before attempting the star test, so I left each scope outside for two hours before I began, more than enough time for everything to equalize.

The star test proved that all four telescopes have very smooth optical surfaces, but also showed signs of spherical aberration, which produces blurry images and is caused by slight inaccuracies in curvature of one or both objective-lens elements. The Stellarvue was clearly the closest to ideal, but the others were well within acceptable parameters. Finally, the Swift showed just a tiny bit of astigmatism, causing a point to appear as a line or an ellipse, but once I loosened the lock ring, the problem vanished, leaving only the slightest signs of spherical aberration.

The Bottom Line

Each of these telescopes is a reasonably good performer both optically and mechanically. Any of the four would give a new stargazer plenty of enjoyment when viewing brighter sky objects. The Stellarvue's optical prowess is especially impressive, although the others also held their own.

Phil Harrington's equipment reviews appear often in Astronomy. *His book* Star Ware *is available through bookstores as well as his website: http//www.philharrington.net.*

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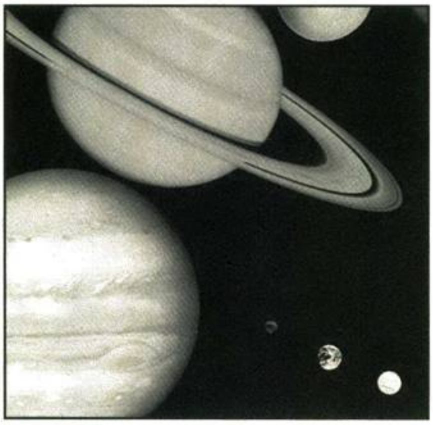

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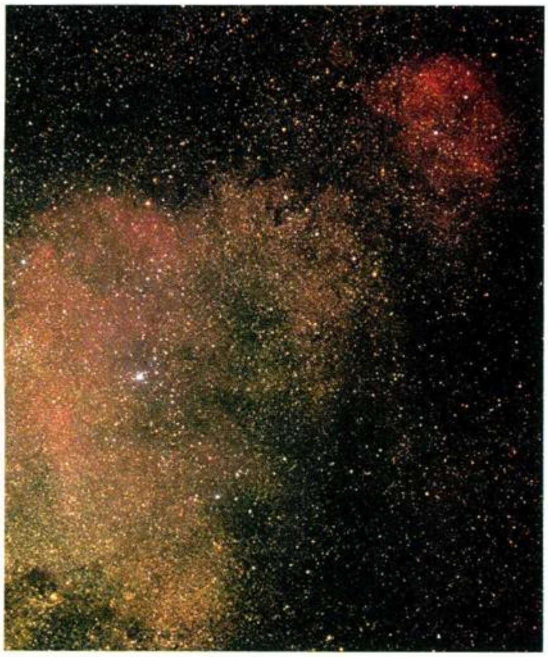
Text by Kelly Kizer Whitt
Photographs by Michael Stecker

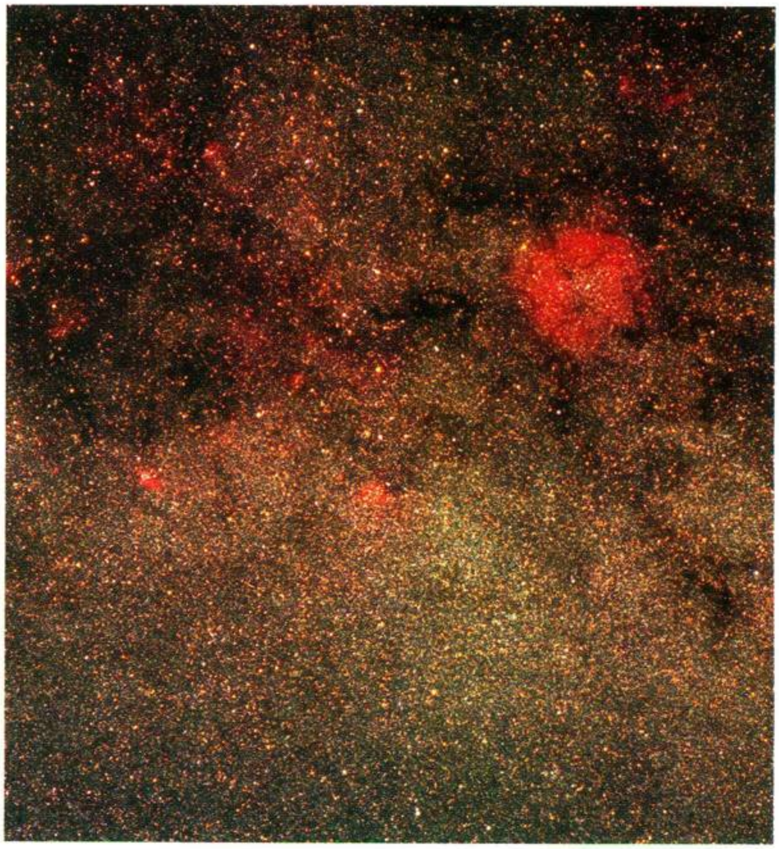
On starry evenings, some of the best amateur astrophotographers in the country gather north of Los Angeles atop Mount Pinos. While many take advantage of the excellent seeing conditions to record objects such as nebulae and galaxies, Michael Stecker prefers lesser-known gems of the Milky Way. An avid astrophotographer, Stecker has traveled to countries all over the world, such as Chile and Bolivia, to capture some of the best views of the night sky on Earth. More than 200 of his photos have appeared in various publications, as well as on television programs, throughout his career. Although he has photographed a wide variety of

Stecker captured vivid detail in this image of B144 (Fish on the Platter), B145, Sharpless 109, Sharpless 101, and Cygnus X-1, a rarely photographed region of the sky.

For more of Michael Stecker's Milky Way images, visit *Astronomy*'s October issue page at www.astronomy.com.



Star clouds are often overlooked by astronomers, yet, as evidenced in these photos, they are some of the most beautiful areas of the night sky. Opposite: the Small Sagittarius Star Cloud; above: the region of Scorpius containing Liller 1, Sh 2-13, and RCW 132.



objects, among his favorites are star clouds. With a pair of Astro-Physics refractors and a Pentax camera, he captures these sumptuous objects on film. The densest of these stellar communities lies along the galactic equator, the circle on the celestial sphere that marks the plane of the Milky Way.

Stecker originally caught the astrophotography bug during the 1986 return of Halley's Comet, but he now concentrates mostly on wide-field images that feature a large variety of objects. "To me, a wide-field vista with binoculars is a more awe-inspiring sight than a single object seen through a telescope," he says.

Stecker also feels that seeing the grandeur of the Milky Way "puts things in perspective," and is a reminder of "how small our planet is relative to our galaxy." He is not drawn just to the brightest and most obvious members of the Milky Way; he also enjoys finding "those rare nebulae that are not charted in some of the amateur atlases."

Beginning on the northern end of the galactic equator are the constellations Cepheus and Cygnus (photo page 78), which float down the galactic river overflowing with stars and nebulae. The prominent red glowing gas of the North America Nebula, along with the Pelican Nebula, marks the northernmost region of Cygnus. The wispy Veil Nebula is one of the few dominant reddish nebulae of Cygnus not clustered along the Milky Way's bulk.

Zeroing in on the central right-hand area of the Swan where the stars are thickest, Stecker has captured an area that teems with activity. Astronomer Bart Bok named dark nebula B144 "Fish on the Platter," (p. 75) which lies nearby other obscuring masses B145 and B146. An interesting astrophysical object, Cygnus X-1 (top right), the first stellar black hole, shares this region with the dark nebulae. Cepheus (above) also holds many cosmic gems, such as NGC 7635, the Bubble Nebula, and fiery red emission nebulae, such as IC 1396.

Traveling south along the galactic equator brings us to Scutum, which holds many obscure yet interesting objects. Dark nebulae such as B110 and B104 (p. 79) are prominent throughout this region, which

Top: This colorful portion of Cygnus holds LDN 857, Sh 101, and Cygnus X-1; above: the Cepheus region of the Milky Way is home to many treasures, such as vibrant emission nebulae.

Above: The Large Sagittarius Star Cloud ranks as our galaxy's brightest star cloud; opposite: at the center of this star-filled area of Scutum lies the dark nebula B110, surrounded by B113, B117a and B119a, and the small hook-shaped dark nebula B104.

Top: The vibrant Scutum Star Cloud has been dubbed "the gem of the *Milky Way.*" Bottom: Southern Cepheus (top) and northern Cygnus (bottom) create a colorful portrait.

is brimming over with stars. The bright star Beta-Scuti also shines prominently.

The most prominent area of Scutum is the Scutum Star Cloud (top), which the American astronomer E. E. Barnard called the "gem of the Milky Way." On the northern edge of the star field lies M11, dubbed the Wild Duck Cluster by nineteenth-century observer Admiral Smyth, who resolved a "V" shape within its stars.

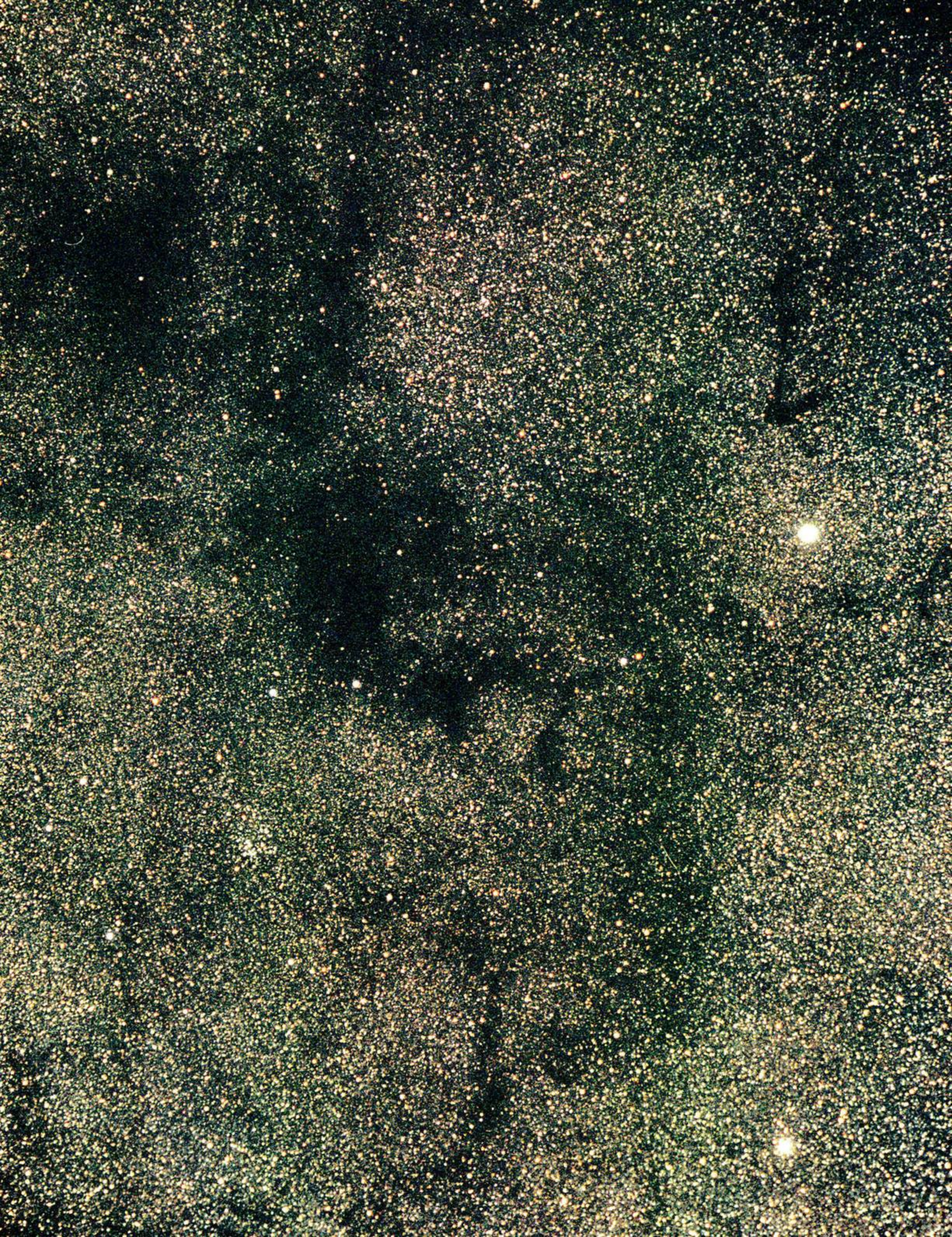
Farther south lies the Small Sagittarius Star Cloud (p. 76), which also bears the designation M24. The open cluster NGC 6603 lies in the northeastern section of the star cloud. The Small Sagittarius Star Cloud can be spotted with the naked eye under a dark sky.

The Large Sagittarius Star Cloud (above) wins the title of the brightest star cloud in the Milky Way. It covers the region of our galaxy with the highest concentration of stars, just east of the galactic center, and makes for a beautiful photographic opportunity. The most notable feature in this swarming mass of stars is the dark nebula-star cluster pair B86/NGC 6520, which lies in the northern half of the cloud.

A small hop south of the galactic center into the corner of Scorpius (p. 77) brings us to the last stop on our photographic tour. This star field surrounds a virtual unknown in the globular cluster category, Liller 1, named after William Liller, the Harvard astronomer who discovered this cluster's dim glow. Located at the southern tip of the orange nebula RCW 132, Liller 1 is invisible in this photo. The region around Liller 1 includes the star cluster M6 and a smattering of bright and dark nebulae. The small red emission nebula Sharpless 13 appears at the upper right of the photo.

So take a journey through these beautiful and often overlooked gems of the Milky Way. Perhaps you'll soon be outside capturing your own photographs of these rich celestial fields.

Kelly Kizer Whitt, former copy editor of Astronomy, *is a contributing editor and freelance writer.*



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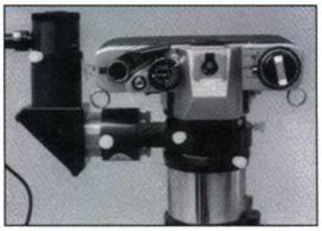

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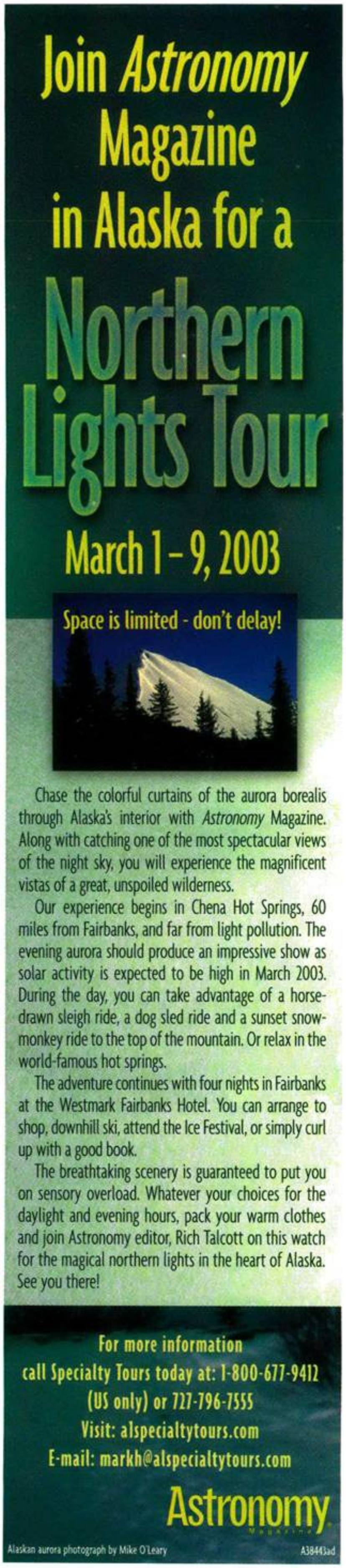
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Alaskan aurora photograph by Mike O'Leary

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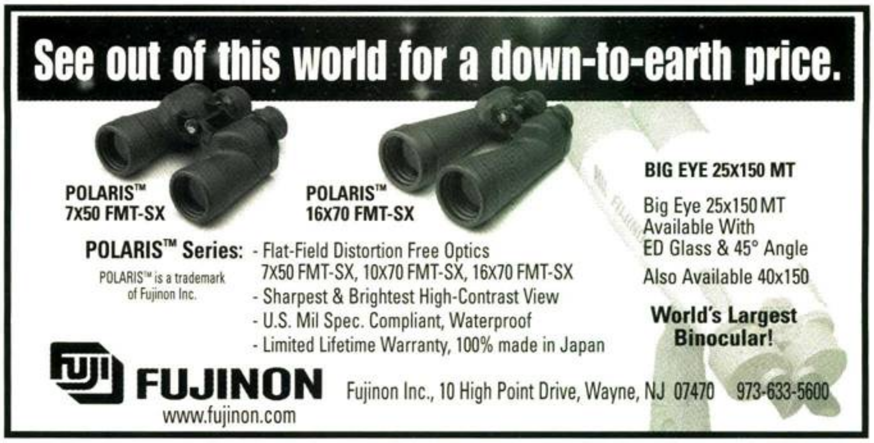
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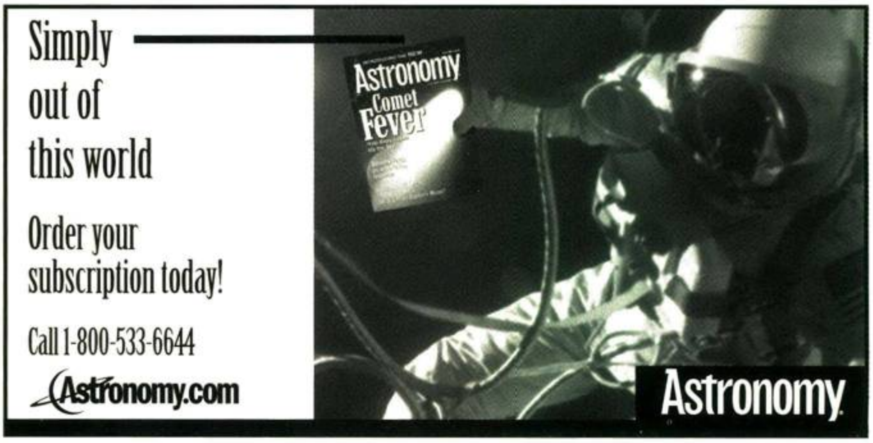

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Beginner's sky

Diary of a neophyte astronomer. by Jerry Burstein

For the past nine months I've enjoyed sharing the experiences my daughter and I have had as novices observing the night sky. Well, as they say, "All things must pass." I've decided to step aside and allow Glenn F. Chaple, Jr., to come in and share his expertise with you starting next month. Residing in Townsend, Massachusetts, Glenn has more than 30 years of experience as an amateur astronomer and is an experienced deep-sky observer and viewer of the planets, comets, variable stars, double stars, and the moon. He has contributed articles on observing and has reviewed telescopes for *Astronomy* for years, and was one of the original writers for the gone-but-not-forgotten *Deep Sky* magazine that was so popular with observers in the 1980s and early 1990s.

Glenn has taught beginning astronomers and has written varied books dealing with this subject, such as *Exploring With a Telescope* (Franklin Watts, 1988) and as coauthor of the *Edmund Mag. 6 Star Atlas* (Edmund Scientific Co., 1982). I'm sure you will not only enjoy reading Glenn's column but will learn a lot from each one as well.

My observing experiences have taught me a lot over the past several months. Let me share with you some of the key points my sidekick and I have learned from our adventures that will forever remain locked in our memory banks.

1 With kids, start slowly and with the easy stuff. Kids can't handle watching something for more than a few minutes (especially things that seem to stand still). Whereas a full moon isn't ideal for stargazing, it's a great way to gain experience with binoculars or a telescope (and provides a high "oooh . . . ah" factor good for keeping early interest levels up). We also were able to keep interest levels high by choosing bright, attractive constellations and asterisms to find with the naked eye.

2 Write down notes of your adventures in a journal or notebook. This will help you remember what you saw, as well as where and when. Add sketches when possible. It's also a great tool to improve writing and creates a wonderful keepsake to share with teachers, family, and friends.

3 Share what you learn with anyone who's interested. This will also help you remember all the great stuff you're finding and impress those around you.

4 There are people all around who are willing to help. Astronomy clubs are numerous and you can probably find one close to where you live. These organizations love to help beginners and take pride in introducing new people to the hobby.

5 You don't have to buy a lot of equipment to get started, but arm yourself with as much reference material as you can handle. You will have lots of questions to answer, both your own and those of your companions, so knowing where to go for quick answers will really help.

Star charts and planispheres are pretty easy to use once you get the hang of them. But even before you spend lots of time outside, read about this great hobby. In past columns I've mentioned several good books that are great to share with kids to help get them started. Here is a listing of some others, both general guides and observing handbooks:

Eicher, David J. *Beginner's Guide to Amateur Astronomy.* Kalmbach Books, Waukesha, Wisconsin, 1993.

Pasachoff, Jay M. *A Field Guide to the Stars and Planets.* [Peterson Field Guide series.] Houghton-Mifflin Co., Boston, 2000.

Ridpath, Ian. *Stars and Planets.* [Princeton Field Guide series.] Princeton University Press, Princeton, New Jersey, 2001.

I'd like to take this opportunity to thank all of the people who've been so kind to send e-mails with suggestions, words of encouragement, and the occasional correction. I still welcome your input, so feel free to write me at jerry@astronomy.com.

Have fun, enjoy what the wonders above have to offer, and clear skies to you all!

WEB 101

Great websites exist that are not only informative but lots of fun for both kids and adults. Here are a few we have enjoyed. (Of course, I shouldn't fail to mention that Astronomy.com is one heck of a place to start.):

- **Astronomy for Kids**
  dustbunny.com/afk
- **Kids**
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- **NASA's site**
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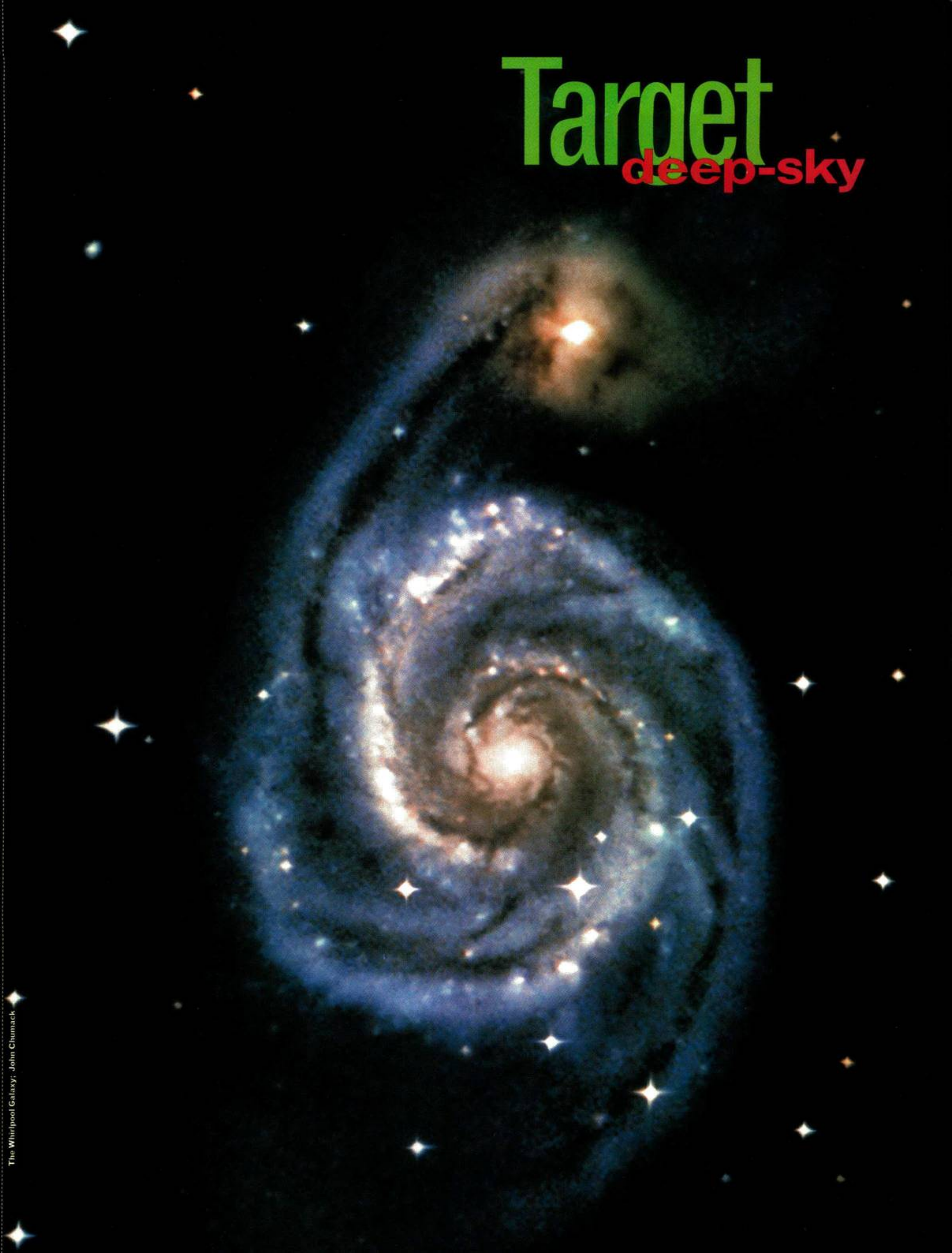


cut along dotted line

The Whirlpool Galaxy; John Chumack

Observing With Class

by Rod Pommier

Edwin Hubble was a cosmic overachiever. Not only did he prove that other galaxies exist, but he also showed they're moving outward in space, providing the first direct evidence of the Big Bang. And he didn't stop there — he devised a classification system for galaxies for which we deep-sky observers will be forever in his debt.

Hubble developed the most widely used version of the system in 1936, ten years after his first draft. The secret of its success lies in its simplicity and usefulness. If you know the Hubble designation of a galaxy you're observing, then you can search for certain structural details typical of that class.

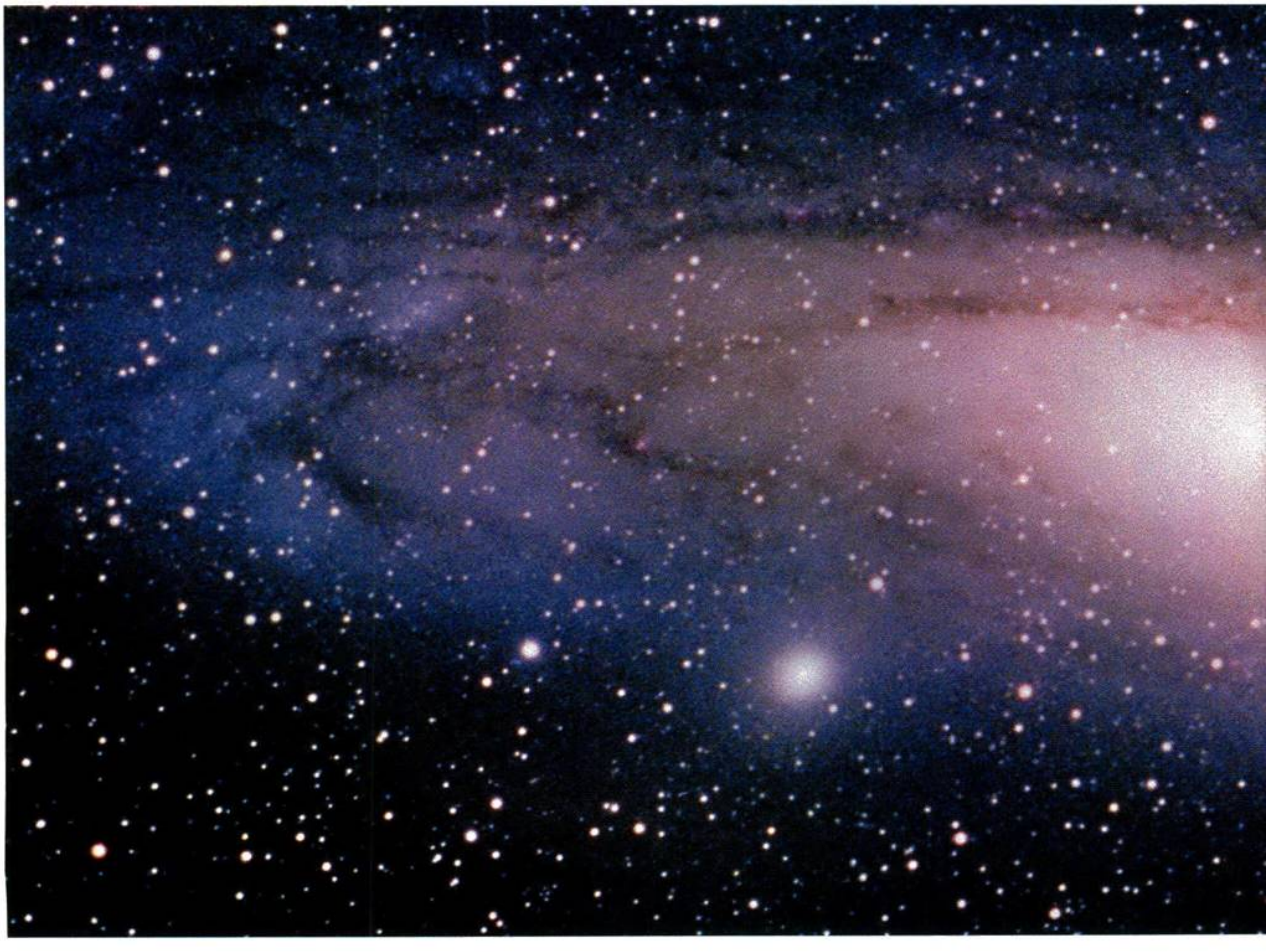
Conversely, when you're not sure what you're dealing with, you can hunt for clues that might reveal the class — and when you find them, suddenly everything snaps into focus. You soon learn to systematically check every galaxy for structural details you might otherwise have overlooked, sharpening your observing skills.

Which One of These is Different?

The Hubble classification of galaxies is easy to remember; it follows a two-pronged "tuning fork" model. Each of the sections of the fork — the handle and both tines — represents one of the three main classes of galaxies: ellipticals, spirals, and barred spirals.

Elliptical galaxies, which make up the fork's handle, are designated by the letter E. They are essentially featureless collections of stars, without any spiral arms or dust lanes. Their lack of dust, as well as their high concentration of red giants, suggests they're a retirement community of older stars, with little chance of producing new stars.

As their name implies, these galaxies are roughly elliptical in shape, and they can be further broken down by how squashed and stretched they appear. Galaxies that look like perfect spheres are dubbed E0, slightly elongated ellipticals are E1, and so on, with cigar-shaped ellipticals classified as E5.



The Andromeda Galaxy, M31, is a classic face-on spiral. Note that the central nucleus is about ⅓ the length of the disk, making it an Sb. Michael and Kelly-Ann Grady

At the dividing point in the tuning fork exists a special, transitional class, known as lenticular galaxies. Designated S0, this type has the familiar discus shape of a spiral, but still lacks spiral arms or dust lanes. The addition of the S0 class was one of the major revisions Hubble made in 1936 — before that, telescopes just weren't powerful enough to differentiate between S0s and ellipticals.

The upper tine of the tuning fork represents the classic spirals, designated by the letter S. These have two main portions — a central bulge, surrounded by a disk with spiral arms.

The ratio of the bulge to the galaxy's diameter is the basis for three subclasses: Anything higher than ⅓ is an Sa, anything about ⅓ is an Sb, and anything lower than ⅓ is an Sc. The spiral arms and dust lanes in the disks also vary by subclass; they are tightly wound around the central bulge in class Sa and loosely wound and highly branched in class Sc.

The lower tine of the tuning fork represents the barred spiral (SB) galaxies. They have a rod of stars that crosses the central bulge. Spiral arms sprout from both ends of the rod — like the streamers on a bicycle handlebar. Barred spirals also fall into three subclasses, SBa, SBb, and SBc, using the same ratio scheme as the spirals.

A fourth, nonconformist, class of galaxies was exiled from the tuning fork by Hubble. Known as irregular (Irr) galaxies, these anarchists seemingly have no esprit de corps, their stars scattered about in no particular order.

Hubble once believed his tuning fork represented a sort of evolutionary branch diagram of galaxies — in fact, his system is also known as "The Hubble Sequence." Galaxies would begin spherical, then flatten as they spun faster, developing ever-widening spiral arms. Eventually, they would scatter their stars into the chaos of an irregular system. While this particular theory is no longer in vogue, there may be some truth to the evolutionary concept.

NGC 3115, seen nearly edge-on, is an S0 because it lacks spiral structure. Kim Zussman

Some astronomers believe that elliptical galaxies, which are made mostly of older stars, form when spiral galaxies collide. Further research may one day give us a comprehensive family history of galactic structure.

Taking Hubble Outside

The night sky offers up a smorgasbord of galactic options to the discriminating amateur. Elliptical galaxies of subclasses E0 through E5 are plentiful in the deep sky, espe-

cially in the Virgo Cluster. Spirals are also abundant, but their appearance depends on how the planes of their disks are aligned with our line of site: We can best observe face- and edge-on spirals. Barred spirals are perhaps the most elusive quarry unless you have a very large scope.

Ellipticals

Perhaps the best-known example of class E0 is the giant elliptical M87 in the Virgo Cluster. One of the largest and most luminous galaxies in the sky, it appears as a 7'-wide circular glow with a bright center, like an unresolved globular cluster.

About 3° northwest of M87 is M86. Compare the oval appearance of this E2 galaxy, which measures 7.4' by 5.5', with the rounder M87.

One of M31's satellite galaxies in Andromeda, M110 (NGC 205), is a large, bright E5. This galaxy, measuring 10' by 5', is so elliptical that it's twice as long as it is wide. Compare it with M31's other satellite galaxy, M32. Did you correctly classify M32 as an E2?

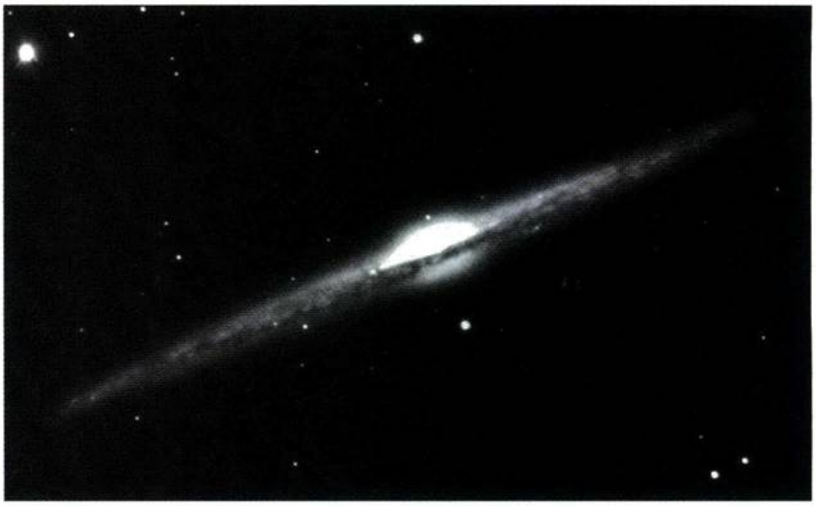
Transitionals

Having covered the base of the tuning fork, we arrive at the branch point, occupied by S0 galaxies. A superb example is NGC 3115 in the little-known constellation Sextans, just south of Leo. It can be difficult to locate due to a lack of field stars, but since S0 galaxies are rare, it's well worth the search.

Measuring 8.3' by 3.2', the bright NGC 3115 (a.k.a. the Spindle Galaxy) exemplifies how you can use visual clues to deduce a galaxy's class. Scopes with apertures larger than six inches reveal a central nucleus that is brighter than the surrounding edges. Too elongated to be an E5 elliptical, NGC 3115 might seem like an edge-on spiral. But look again: the galaxy's edges taper too smoothly from its wide middle to its pointy tips — there is no central bulge — and an equatorial dust lane or spiral arms are nowhere to be seen.

Classic Spirals

For our trip down the tine of classic spirals, we'll need to put on our Sherlock Holmes caps again. Appropriately enough, we begin with the whimsical Sombrero Galaxy, M104, in Virgo. Its large central bulge doesn't taper smoothly to the tips — the disk can be seen projecting a short distance on either side, a telltale sign of a classic spiral. And the bulge occupies more than ⅓ the diameter of the galaxy, so it has to be an Sa.

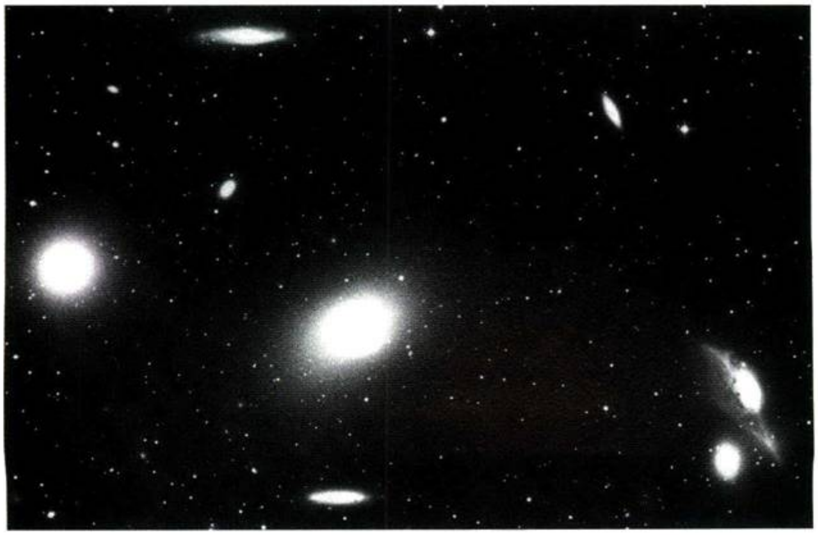


Like M31 on the previous page, NGC 4565 is an Sb, but it is seen edge-on, bisected by a dust lane. Chuck Vaughn

M104's disk is inclined a mere 6° to our line of sight, so it's nearly edge-on, with the equatorial dust lane bisecting the disk. Note that the dust lane is bowed slightly to the south because of the angle of inclination. Another example of an Sa galaxy that is almost precisely edge-on is M102 (NGC 5866) in Draco, but for some reason the dust lane can't be seen projecting out on either side of the central bulge.

Observable Sb galaxies are practically a dime a dozen, such as the star-party standbys M31 in Andromeda and M81 in Ursa Major. These galaxies look like large, fuzzy oval disks with bright central nuclei about ⅓ the length of the disks. Other face-on Sb galaxies include M64, the Blackeye Galaxy, in Coma Berenices; M65 and M66 in Leo; and M106 in Canes Venatici.

Two excellent edge-on Sbs are NGC 4565 in Coma Berenices and NGC 891 in Andromeda. To find NGC 4565, point your finder scope at the Coma Cluster. Center the star 17 Comae Berenices in your scope and sweep 2° due east. Through a 6-inch scope, you'll see a faint spindle of light with a fainter central bulge projecting above and below it. An 8-inch scope will reveal more — a dark dust lane bisecting the galaxy



The Virgo Cluster is home to a menagerie of galaxies. *Compare M84, the round S0 at far left, with the elongated elliptical* M86, an E2 at center. Martin C. Germano from tip to tip.

To find NGC 891, center the bright star Gamma Andromedae in your scope and then sweep 3.5° due east. NGC 891 is extremely faint, so use your peripheral vision to find it. I've seen the dust lane crossing the central bulge with my 14-inch SCT, but not with my 8-inch.

A classic example of a face-on Sc galaxy is M33 in Triangulum. A large, hazy oval, it is emblazoned with S-shaped spiral arms, which are open, as we'd expect of an Sc galaxy. The central bulge is so small it looks like a star, making the bulge-to-disk ratio significantly less than ⅓. Another fine Sc galaxy is M51 in Canes Venatici. M51 exhibits a more prominent central nucleus and brighter spiral arms, but again the ratio remains far less than ⅓. A third example, NGC 253 in Sculptor, has dust lanes that mottle its spiral arms.

As for edge-on Scs, NGC 5907 in Draco makes for great viewing. A mere sliver of light 12.3' by 1.8' wide, it has a small central bulge punctuated by a stellar nucleus.

Barred Spirals

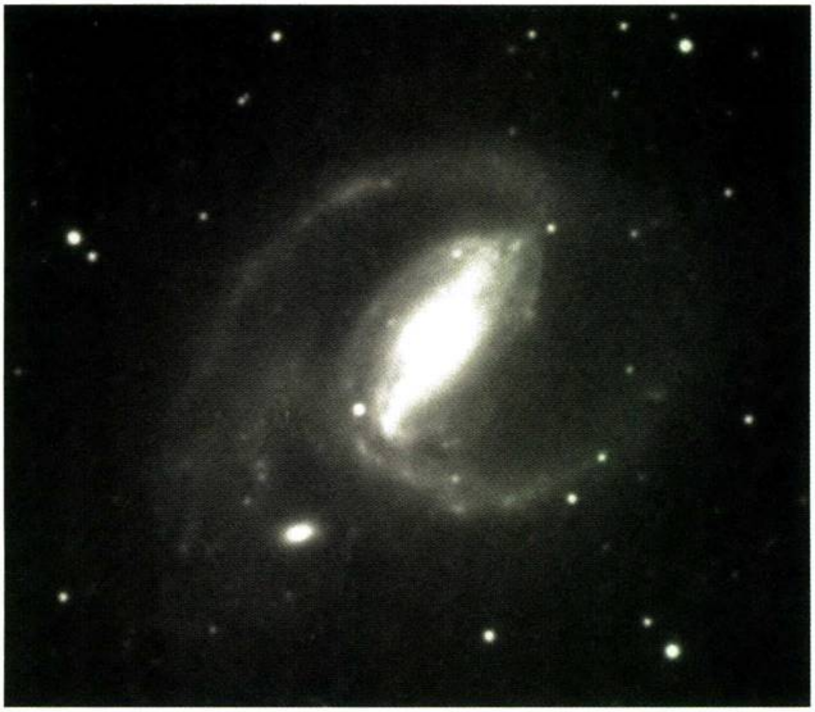
I know of only one example of a barred spiral in which the bar is observable. This is the SBb galaxy NGC 1097 in Fornax. Since it lies at a declination of –30°, many northern observers have never attempted to observe it. NGC 1097 appears as a faint oval of light with a bright nucleus occupying about ⅓ the diameter of the galaxy. On clear, dark nights, when NGC 1097 is near the meridian, 6- to 8-inch scopes clearly show a distinctive bar running across the galaxy from northwest to southeast. Hints of spiral arms can be seen trailing off the ends of the bar.

Barnard's Galaxy, NGC 6822, is irregular, as it lacks a defined shape. James R. Foster

Irregulars

If you live near the equator or in the Southern Hemisphere, then two spectacular naked-eye irregulars are yours for the viewing. These are the Large and Small Magellanic Clouds, which are the two satellite galaxies orbiting our Milky Way. Tidal interactions with our galaxy may have been responsible for scattering their stars so haphazardly. Exploring these galaxies — even with binoculars — is an experience so awe-inspiring it defies description.

If you live in northern latitudes, though, don't despair. At a declination of –15°, NGC 6822, also known as Barnard's Galaxy, is a large, faint irregular that resembles the Magellanic Clouds. Counterintuitively, the larger the scope you view it with, the more difficult it is to see. In a 4-inch refractor, it's a faint, diffuse glow with no detectable structure. In fact, it looks more like a gaseous emission nebula than a galaxy. Through my 8-inch SCT, it looks like a barely perceptible increase in the apparent brightness of the background sky — it has no distinct borders. Through my 14-inch SCT, I can't make it out at all. E.E. Barnard, who discovered the galaxy in 1884, described it as "fairly conspicuous" through a 4-inch at low power, and "barely discernible" through the 100-inch Hooker telescope at Mt. Wilson.



NGC 1097, an SBb, is one of the few observable barred spirals. Martin C. Germano

Go back to M51, the Whirlpool Galaxy, and scrutinize its companion NGC 5195. Note its irregular patch shape peppered with dust. Tidal interactions with the Whirlpool have scattered NGC 5195's stars into chaos, ruining its standing as a classic spiral.

The deep sky is filled with galaxies of all shapes. Now that you know the Hubble classification scheme and how to use it at the eyepiece, you can sweep the skies for galaxies and scrutinize them for clues that will reveal their classes. Check your guesses with observer's manuals. You'll start to notice more detail than you ever thought possible, and you just might sharpen your sleuthing skills in the process. ■

Rod Pommier is an associate professor of surgery at Oregon Health Sciences University in Portland. He has been an avid amateur astronomer since he was 12.

PRODUCTS

Sky-Cam II Video Camera

Astronomy is often a lonely pursuit. Even at star parties, observers may feel as if they are "alone together," with each seeing his or her own view through the eyepiece. Now, a new video camera from AstronomyQuest.com makes stargazing a communal experience.

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BOOKS

Letters to Father: Suor Maria Celeste to Galileo, 1623 – 1633

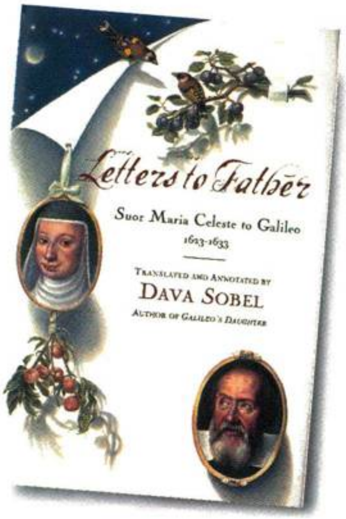
Translated and Annotated by Dava Sobel, 377 pages, Walker & Co., New York, 2001; ISBN 0-8027-1387-4; hardcover, $40.

He was an intellectual giant of the 17th century, the first person to construct a complete telescope and turn it heavenward, revealing spots on the sun and mountains on the moon. His discovery of four satellites orbiting Jupiter supported the idea that Earth orbits the sun — not vice versa. It was for this belief that he was convicted of heresy by the Catholic Church and placed under house arrest for the remainder of his life. He was Galileo Galilei, a scientist renowned for his inspired discoveries. Very few of us, however, know a great deal about Galileo the man.

Although he never married, Galileo had three children — two daughters and a son — over the course of his 12-year relationship with Marina Gamba of Venice. Both daughters were sent to live in the Convent of San Matteo just south of Florence in their early teens. The son lived with Galileo in the latter part of his youth, studied at the University of Pisa, and later married and had several children.

Galileo's elder daughter, Virginia, who adopted the name Maria Celeste in honor of her father's passion for all things celestial, carried on a regular correspondence with him until her death at 33. *Letters to Father*, translated and annotated by Dava Sobel, is a collection of 124 surviving letters written by Suor (Sister) Maria Celeste in the last decade of her life.

Suor Maria Celeste, despite her mild self-deprecation of her own intellectual faculties, was clearly a remarkable and brilliant woman. She served as convent apothecary and choir supervisor, composed letters of official business for the mother abbess, and performed a multitude of other daily tasks. In addition, Maria tended to many of the needs and desires of her beloved father: She mended his shirts, prepared his favorite confectioneries, and even took care of his household affairs during the year in which he stood trial for heresy.


Letters to Father
Suor Maria Celeste to Galileo
1623-1633
Translated and Annotated by
DAVA SOBEL
Author of Galileo's Daughter

She was an industrious and deeply religious woman who was strongly devoted to her father, her younger siblings, and her fellow sisters at the convent. Her letters show that, despite her cloistered and pious existence, she was exceptionally well-informed and open-minded.

We also see her grow as a person; many of her early letters seem shy and tentative in their requests, whereas later letters show more confidence. Sometimes she even chides her father, however gently. Still, her letters are always respectful and loving.

Maria's correspondence provides a fascinating historical account of life and family in the 17th century, a time racked with religious and scientific upheaval, when people were terrorized by bubonic plague and other rampant ailments. It also lends invaluable insight into Galileo himself.

From Maria's letters we see that Galileo was a loving and attentive father and an extremely generous person. He presented gifts of food, wine, cloth, and much more to the sisters in Maria's convent and often interceded on their behalf with his powerful friends in the church (these friends weren't able to help him with his own conviction, unfortunately). Maria's letters invariably included at least one request and, from the thanks she expressed in subsequent letters, it appears that he never denied her. We also see that Galileo had numerous friends ranging from politicians to scientists to high-ranking clergy.

Letters to Father begins with a brief but enlightening introduction in which Sobel summarizes some basic Galilei family history and makes some important points regarding social etiquette in the 17th century. This handsomely crafted book contains both Italian and English versions of each letter with descriptive notes as needed.

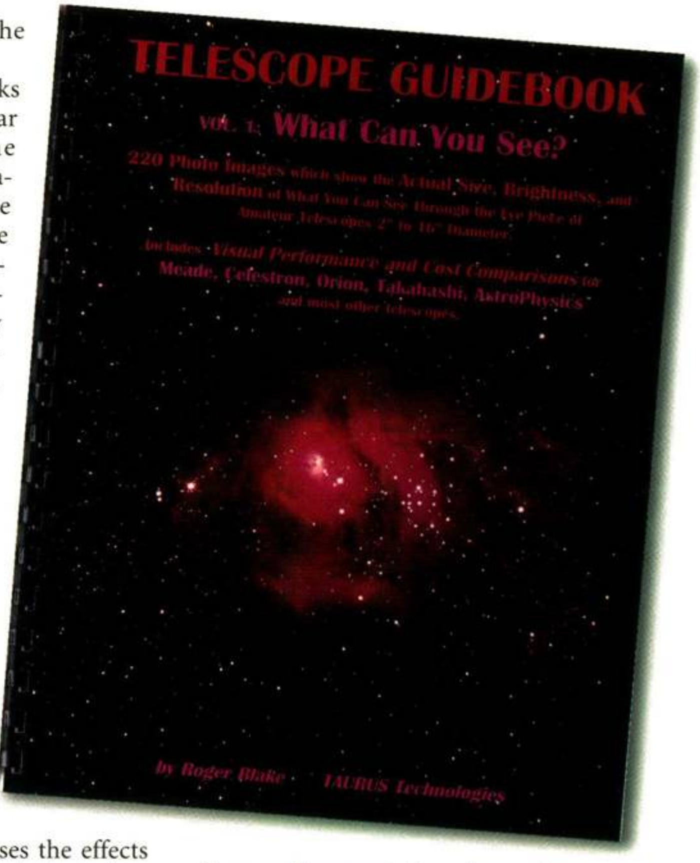
The book is so absorbing it stands on its own merit, but it also makes an indispensable companion to Sobel's earlier work, *Galileo's Daughter*, for which Suor Maria Celeste's letters provide much of the foundation. — *Jennifer Birriel teaches physics at Morehead State University in Morehead, Kentucky.*

The Telescope Guidebook Vol. 1: What Can You See?

Roger Blake, 158 pages, Taurus Press, Woodstown, New Jersey, 2001; ISBN 0-9710924-0-0; softcover, $39.

There is no shortage of "how-to" books for beginning and advanced amateur astronomers. Many of these handbooks fail, however, to adequately address a critical question: What do you really see when peering into the eyepiece of a telescope?

Astronomy guidebooks with pages of spectacular Hubble closeups of the planets or colorful observatory portraits of nebulae and galaxies do a disservice to their readers — especially novices. What disappointment when they encounter the backyard-telescope reality of a minute planetary disk or pale fuzzy patch of light!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by Roger Blake
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In *What Can You See?* author Roger Blake "shows it like it is." More than 200 computer-generated photo images, mostly black and white, replicate the actual appearance of the moon, the major planets, and deep-sky objects as viewed through telescopes ranging in aperture from 2 to 16 inches. Blake even addresses the effects of light pollution, atmospheric seeing, pupil diameter, nebula filters, and averted vision.

What Can You See? begins by briefly detailing the purpose and scope of the book and describing various sky targets the reader might encounter. The requisite full-color photos are included, but Blake openly credits their origins (the planet photos are from Hubble, while the deep-space objects were photographed through a 10-inch Newtonian reflector).

The heart of Blake's work begins in Chapter 3, "Telescopic Views of the Moon and Planets." After demonstrating the effects of aperture and atmospheric conditions on resolution, Blake shows how Mars, Jupiter, Saturn, and the moon appear in various telescope apertures. The images are fairly true-to-life, except that they appear only in black and white. Color photographs, along with a demonstration of the effects of color filters on lunar and planetary detail, would have been a welcome addition.

Chapter 4, "Telescopic Views of Star Clusters," takes the reader into deep space, showing multiple aperture views of the open cluster M103 and the globular cluster M13. As with the planet images, Blake assigns magnifications appropriate for each aperture range. With a little effort and interpolation, the reader can determine the most realistic view obtainable through any given telescope.

The most complex and extensive of Blake's efforts is Chapter 5, "Telescopic Views of Nebulae and Galaxies." Five sets of photos compare combinations of variables, such as brightness vs. magnification, image brightness vs. pupil diameter, and image brightness vs. light pollution. Then comes a section of photos of the Whirlpool Galaxy and the Crab, Orion, and Dumbbell nebulae, grouped so that each page corresponds to a given brightness level and magnification. Beginners may have a little difficulty understanding this section.

Closing chapters include a guide to major telescope models and a primer on scope optics, which would better serve the reader earlier in the book.

For beginners trying to select a first telescope that satisfies their observing requirements, or the expert curious as to how sky objects might look in a second telescope, this book will serve as a handy reference. *What Can You See?* should be included in the library of any astronomy club. — *Glenn Chaple has been an enthusiastic amateur astronomer for more than 30 years. He lives in Townsend, Massachusetts.*

The Webweaver Picks

by Richard J. Bartlett

Do YOU have a science question?
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Calling All Kids!
Today's Feature

Winter is on its way and so are the clear, dark nights. If you have children, they might already be interested in astronomy. If not, now's a good time to introduce them to the stars. There's a virtual universe of information available for kids online.

A good place to start is at KidsAstronomy.com. As with most of the educational sites, there are different sections covering the various aspects of astronomy, including the planets, space exploration and the universe in general. Best of all, there are two astronomical courses online. One is aimed at children aged 7 to 11 and the other for children aged 12 to 18. There's also a section for teachers with work sheets and lesson plans for children of all ages. To visit the site, go to http://www.kidsastronomy.com.

Another cool place is the appropriately named Astronomy for Kids website at http://www.dustbunny.com/afk. It's nicely designed, easy to use and – best of all – it's up-to-date. It also doesn't dumb the material down. Unfortunately, there's very little on the constellations.

Nowadays kids are often glued to the television for hours on end, but not so very long ago they would sit, rapt, in front of the radio. There are several radio shows devoted to astronomy that broadcast daily. At least two have their own websites.

For starters, there's *StarDate* at http://www.stardate.org. The site is comprehensive; the solar system and most of the constellations are covered, an almanac highlights the current month's celestial attractions, and one page graphically displays the phases of the moon from 1951 to 2015.

There's also a show called *Earth & Sky* that is broadcast daily from the University of Texas in Austin. The site contains details of today's episode and what to look for in the sky tonight. You'll find it at http://www.earthsky.com.

Both shows allow you to listen online and can be heard through affiliate stations across the United States. *Earth & Sky* can also be heard in Canada and internationally through the World Radio Network.

Younger kids will get a kick out of Arty the Part-Time Astronaut at http://www.artyastro.com/artyastro.htm. You'll find games and activities to help your child learn about the planets, the phases of the moon, telescopes, and space in general. There's also a guide for parents and teachers that can be downloaded and printed.

NASA and the Jet Propulsion Laboratory (JPL) have created several sites for children. JPL has a Space Place at http://spaceplace.jpl.nasa.gov/spacepl.htm. Like the first two sites, it's interactive and has a number of different things for kids to do while learning about the universe. Be warned though: Some of the games are simple in concept but quite addictive in practice — even for adults!

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NASA's website for younger kids can be found at http://kids.msfc.nasa.gov. Here they can learn about spacecraft, the solar system, and space in general. They can also track satellities, the shuttle, and the International Space Station, and even submit some of their own sky-related artwork.

For older children, NASA has the Liftoff site that tends to focus on spacecraft. Parts of it are out of date and generally speaking, it's not the easiest site to navigate but it's still worth a visit. Look out for the interactive 3-D solar system. Liftoff can be found at http://liftoff.msfc.nasa.gov.

If you're a high-school teacher, you might be interested in the Telescopes In Education (TIE) website at http://tie.jpl.nasa.gov/tie. This project allows students from around the world to remotely control a 24-inch telescope and charged-coupled device (CCD) at the Mount Wilson Observatory. Students from as far afield as Canada, England, Japan, and Australia have participated and conducted valuable research. Maybe you know a school with an astronomy club that might be interested in taking part.

Finally, students can get creative at ThinkQuest, a non-profit that promotes education through technology. Every year students from around the world submit educational websites they have created on a variety of subjects. The project isn't confined to schools — parents and youth groups can also participate. ThinkQuest can be found at http://www.thinkquest.org. To find your way to the astronomy sites, click on Libraries, select the ThinkQuest Internet Challenge Library and then select the Science section. "Astronomy & Space Exploration" is near the top of the list. Alternatively, if you're a careful typist, point your browser to http://www.thinkquest.org/library/cat_show.html?cat_id=40&cid=1.

This Halloween it's worth reminding your kids there are other kinds of treats besides candy. Get them looking up at the stars and they'll find a universe of puzzles and wonders that will fascinate them for the rest of their lives.

— Visit Richard's StarLore website at http://www.starlore.net.

Astronomy's Marketplace

Welcome to the MARKETPLACE section in ASTRONOMY Magazine. These pages are specifically designed to be an affordable and highly effective way for you to market astronomy-related products or services. Call Ken Kozerski at 888-558-1544, ext. 636 to place your advertising message here.

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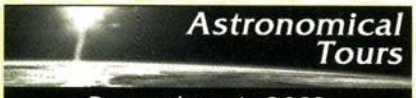

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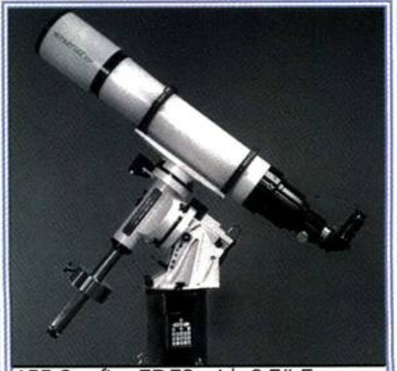

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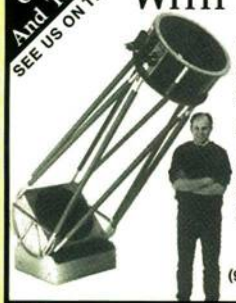

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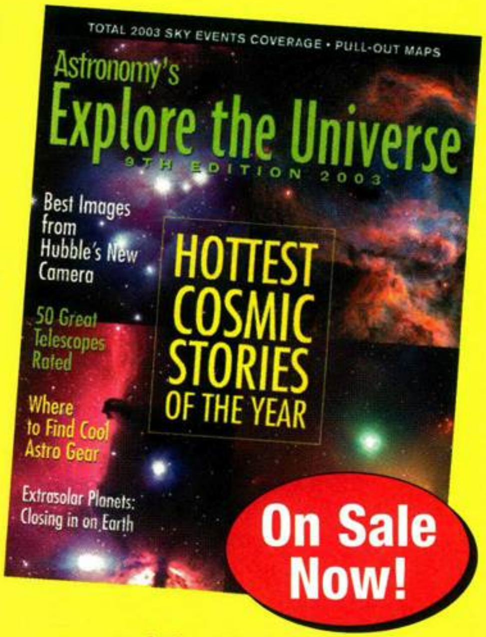
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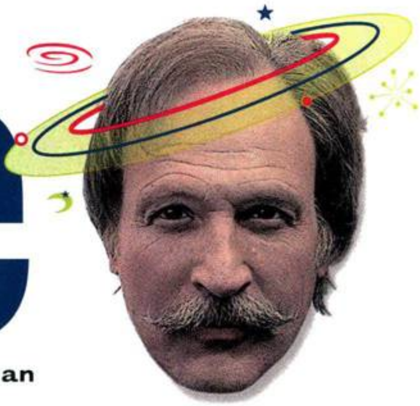


by Bob Berman

What's In a Name?

Names have power. Catchy ones stay with us, dull ones earn obscurity. Celebrities know this, which is why Reginald Dwight and Cherilyn Sarkisian decided to call themselves Elton John and Cher. But when it came to naming the universe's contents astronomers somehow established a quirky, inconsistent system that rarely gives objects titles worthy of their grandeur.

Take the stars. Only three dozen bear traditional names still in common use. Some sound dignified (Arcturus), some ridiculous (Zubeneschamali), and some embarrassing (Scheat). Some star names appear reasonable (Dubhe) but make people laugh when they're pronounced correctly ("Look at Dubby!"). If you try to justify odd names by explaining their meaning, it doesn't usually help. Tell people that Alpheratz, Betelgeuse and Deneb mean Horse's Belly Button, Armpit of the Sheep, and Chicken's Tail, and the stars may still lack the glamour of the Hollywood variety.

At least such proper names provoke interest and recall ancient mythologies. The second, medium-bright tier of stars, however, do no such thing: Bearing only Greek letters, they have the advantage of being logical and sounding stately. No alien would be ashamed to come from Omega Herculis or Gamma Tauri.

But then comes the third category of stars, the faint ones comprising the vast majority. Here we run into competing naming systems, all of which use numbers. You can call the star orbiting the Cygnus X-1 black hole HDE 226868 or else BD +34°3815. You can even use designations from a host of disparate catalogs that are still widely used: the fifth and sixth nearest stars to Earth are commonly called Lalande 21185 and Wolf 359. Somehow such inconsistent terminology all remains in place, sometimes thrown together in the same spot, as in the famous double cluster h and χ Persei.

Move to the planets. Trivia question: What's the only planet bearing the name of a Greek god? Answer: Uranus. It alone was shared by both Greeks and Romans; the rest are strictly Roman. As for major planetary features, they sound like they were named by morons. The Great Red Spot. The B Ring. The A Ring. The Dark Spot. Hello? Who's responsible for this?

Moons are something else again, with the power to please anyone who finds inconsistency delightful. Mars's satellites, Fear and Death (Phobos and Deimos) take the "least pleasant" prize and come from Greek mythology, as do most planetary moons. But Uranus's satellites are all characters from Shakespearean plays, which is why there's an actual place in space named Puck. Go figure.

Asteroids started out as Greek mythology, then changed over to being a modern popularity contest judged by the folks on the naming committee of the International Astronomical Union. Deceased, and even some living, astronomers and physicists get honored with their own namesake chunk of rock. Eros floats next to Shoemaker.

Meteoroids and their showers are named for constellations, meteorites for whatever place on Earth they smashed into. Comets are the sole objects named for the person who reported it first. This is the only possible way to get your name emblazoned in the heavens and uttered by everyone — if the comet brightens spectacularly. It's a wonderful contest that inspires backyard amateurs around the world to learn the sky. And why not? Students busy shivering away their youth at the eyepiece are not robbing convenience stores. The winner then even becomes the sole authority on how the celestial name is to be pronounced.

Next come the floating Rorschach inkblots called nebulae, ideal for probing the strange workings of astronomers' cerebral cortexes. At some point someone imagined that a particular gas cloud looked like a dumbbell from the weight room at the local gym (a place not generally frequented by astronomers, if you check out the bodies plopped next to you at the next convention). The "Dumbbell Nebula" label stuck, as did the results of 18th and 19th century astronomers saying, hey, look at that: An Eskimo! And there's a cat's eye staring right at me! And whoa, check out the Owl! Much observing was apparently done before the "Just say no!" campaign took hold.

Despite the fact that more backyard telescopes are now routinely trained at the heavens than ever before, there are still lots of unnamed blobs of dusty hydrogen out there, and the Internet provides better communication than ever, yet the odds of getting people and books to start alluding to it the way you do are almost nil. The late Robert Burnham Jr. called the Eagle Nebula "the Star Queen Nebula," a lovely and more accurate match of the cloud's actual appearance, yet despite his wonderful handbook's enormous popularity the new label never caught on. Too bad the status quo is so unyielding. It would be nice to spice up the firmament with names that are cool (the Matrix Nebula), bestow honorific titles (The Captain Picard), or tell future generations about cherished aspects of our lives (the Nacho Nebula).

Finally we come to the largest and grandest structures in the cosmos — galaxies. We've seen that each type of celestial object has its own separate naming system (and we skipped right over variable stars, radio sources, and others). In this whole celestial menagerie, galaxies are unique, having gotten their start when only a single example was known, back when many cultures regarded the glowing sky-belt as a band of spilt cream. Latin speakers called it Via Galactica — Milk Street, or Milky Way. When other galaxies were first recognized just 75 years ago, the galactic theme was retained: The word "galactic" even contains "lactic" and suggests that the whole universe is one vast Dairyland.

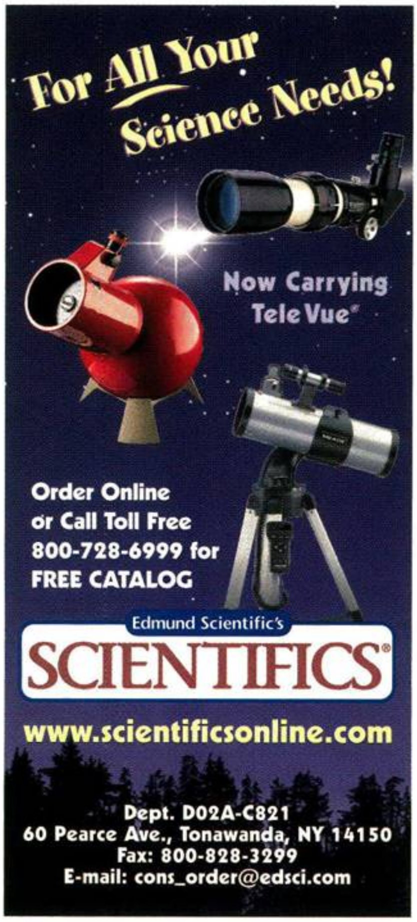
So how to name them? Since consistency within categories is usually the rule, we could have kept the Milky Way motif and given new galaxies labels like Twix and Almond Joy. Or we might have milked that dairy theme by naming them after various cheeses, or ice cream flavors, and now be reading about a supernova in Butter Pecan 4. Instead, only a few dozen galaxies wound up with any sort of name at all.

And uniformity played no role. Some were named for articles of clothing (the Sombrero) or specific injuries (the Black Eye). The huge majority merely received number designations, which makes sense since there are 200 billion galaxies while English has only 200,000 words and nearly all are poor potential candidates like "however" and "rat."

There's no way all known galaxies could be named unless each and every English word was shared by a million galaxies, as in Rat 334792, but then we'd pointlessly be back to consisting of mostly numbers anyway.

So the universe's inventory will stay just the way it is. We took no part in its naming, but that's okay. NGC 4565, by any other name, would look just as pretty — to Cher or anyone else.

Bob Berman regularly writes Astronomy's "Strange Universe" column. He is also the author of entertaining and inspiring guides to the night sky, including Secrets of the Night Sky *(HarperPerennial, 1996).*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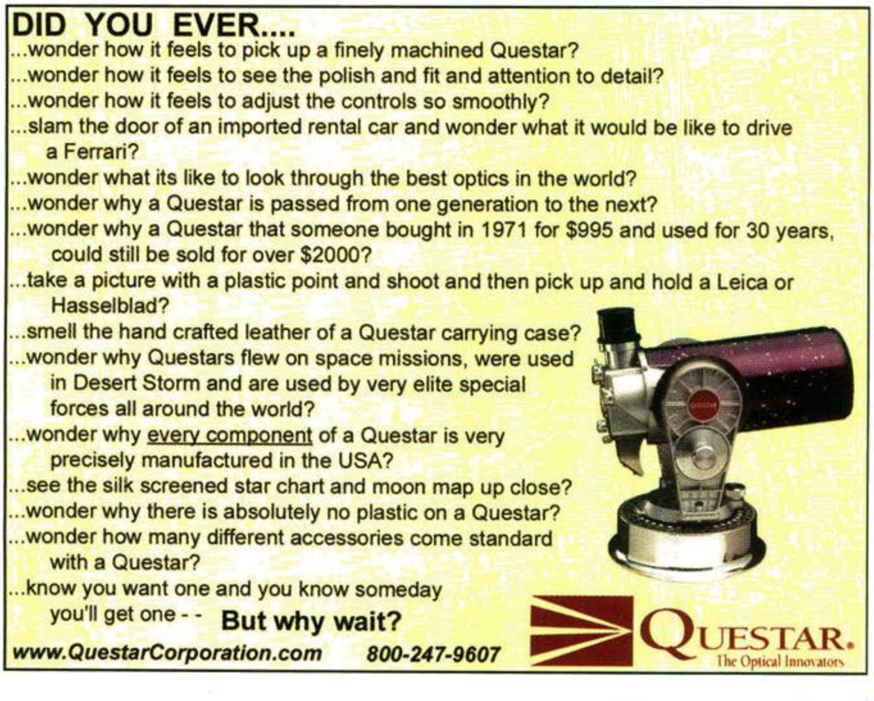
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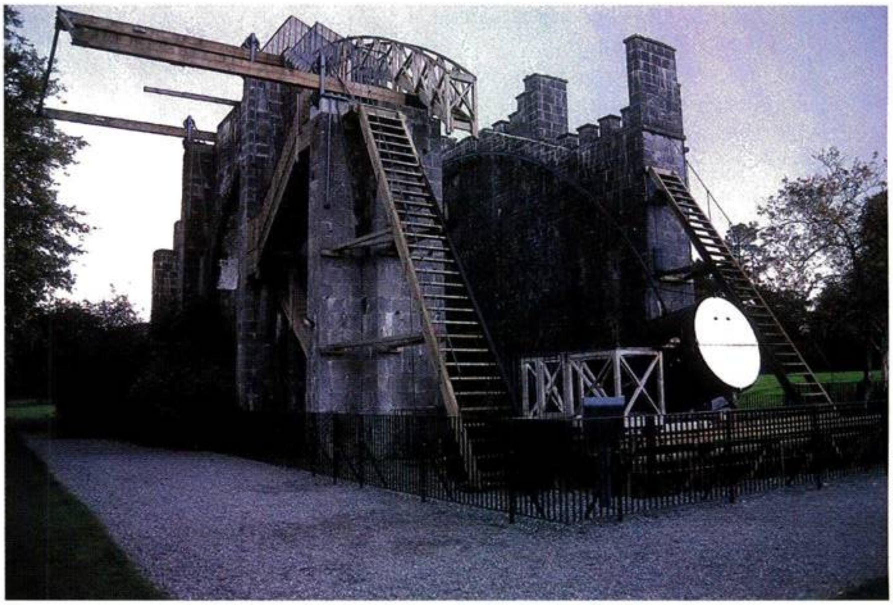
The 2002 event will feature John Dobson of Dobsonian fame, astrophotographer Jack Newton, Barrie Jones from Open University, Nobel Laureate Antony Hewish, and a number of other prominent speakers.

For more information, visit the Shannonside website at http://www.geocities.com/shannonsideac/whirlpol.htm.



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Golden Pond Observatory, Land Between the Lakes, Kentucky. Sponsored by the Western Kentucky Amateur Astronomers. Weekend events include observing, informal talks, and contests. For more information, visit its website, http://wkaa.net/.

OCTOBER 2–6
No Frills Star Party

Tuckahoe State Park, Queen Anne, Maryland. Presented by the Delmarva Stargazers, this is the eighth annual No Frills Star Party. For more information, contact Lyle Jones, (302) 736–9842, 230 N. Bradford Street, Dover, DE 19904; e-mail, lyjones@state.de.us; website, http://www.delmarvastargazers.org.

OCTOBER 3–6
Enchanted Skies Star Party

Socorro, New Mexico. Offering clear, dark skies and a genuine taste of the great American Southwest, the Enchanted Skies Star Party has drawn astronomy enthusiasts from around the world. The 2002 keynote speaker is Stephen Maran. For more information, visit the Socorro Chamber of Commerce's website, http://socorro-nm.com/starparty.

OCTOBER 3–6
Peach State Star Gaze

White Water Express, Georgia. The PSSG features speakers David Levy and Will Tirion. For more information, visit the Atlanta Astronomy Club's website at http://www.atlantaastronomy.org/.

OCTOBER 4–6
Eastern Iowa Star Party

Wapsi River Environmental Education Center, Dixon, Iowa. For more information, e-mail Cecil Ward at occular30mm@yahoo.com.

OCTOBER 4–5
Fall Central Texas Star Party

Canyon of the Eagles Nature Park, Burnet, Texas. Sponsored by the Austin Astronomical Society, this twice-yearly star party affords amateurs an opportunity to observe under some of the darkest skies in Texas. For more information, e-mail, aas-info@kirchhof.com; website, http://www.austinastro.org.

OCTOBER 5
VAAS Convention

Randolph-Macon College, Ashland, Virginia. Sponsored by the Richmond Astronomical Society. The day features speakers and observing. For more information, contact Terry Barker, (804) 379–8175; e-mail, tbarker@i2020.net; website, http://www.richastro.org.

OCTOBER 10–19

World Space Conference

George R. Brown Convention Center, Houston, Texas. Gathering more than 13,000 leaders in science, engineering, industry, and policy from over 100 countries, this is the largest space conference ever. For more information, visit the AIAA's website, www.aiaa.org/wsc2002.

OCTOBER 12

LVAAS Star Party

South Mountain, near Allentown, Pennsylvania. Hosted by the Lehigh Valley Amateur Astronomical Society. For more information, visit its website, http://www.lvaas.org/.

OCTOBER 12

North Valley Star Party

Horseshoe Lake, Upper Bidwell Park, California. Presented by the North Valley Astronomers, observing begins at 7 P.M. For more information, visit its website, http://www.rigel.csuchico.edu/nova/.

OCTOBER 12

NOVAC Star Gaze

Franklin Park, Purcellville, Virginia. Sponsored by the Northern Virginia Astronomy Club. For more information, visit their website, http://novac.com/.

OCTOBER 12

ScopeOut Telescope Fair

Cincinnati Observatory Center, Cincinnati, Ohio. Daytime activities are from 12 P.M. through 5 P.M., followed by observing through historic 12-inch and 16-inch telescopes. For more information, contact the Cincinnati Observatory Center, (513) 321–5186; e-mail, foto@one.net; website, http://www.cincinnatiobservatory.org/calendar.

OCTOBER 30–NOVEMBER 3

Deep South Regional Stargaze

Percy Quin State Park, McComb, Mississippi. For more information, contact Barry Simon, (504) 283–7592; e-mail, bsimon615@aol.com; website, http://www.nightskydesign.com/pas/dsrsg.html.

CONTACT

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Add your events to our online calendar at http://www.astronomy.com.

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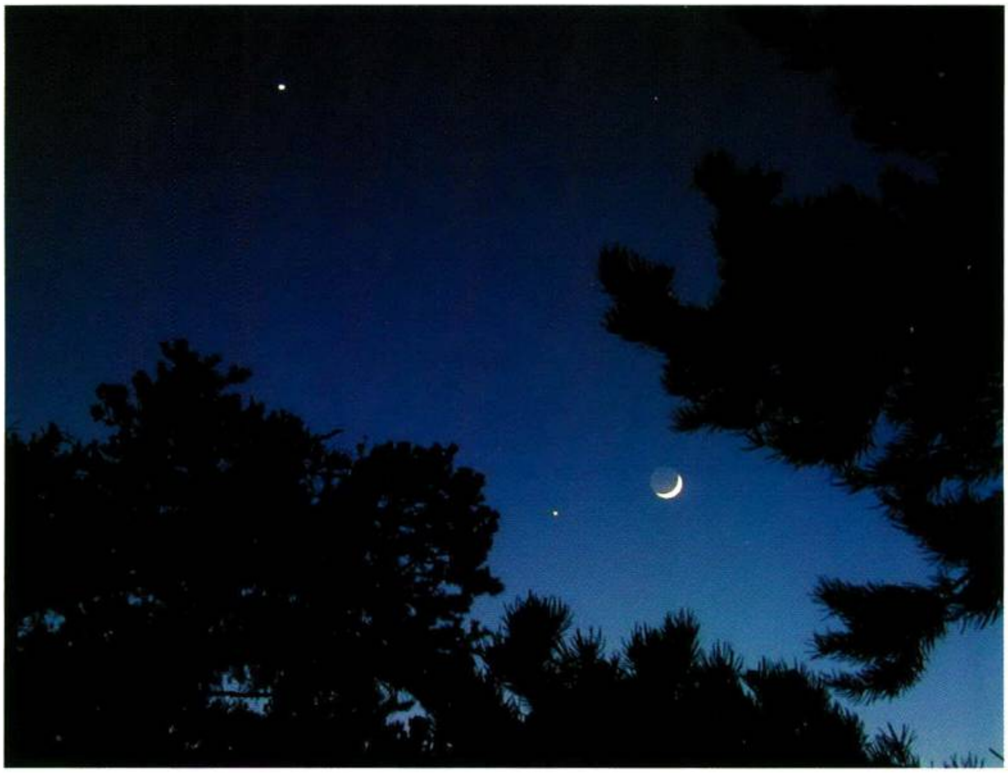
ASTRO JOURNEYS

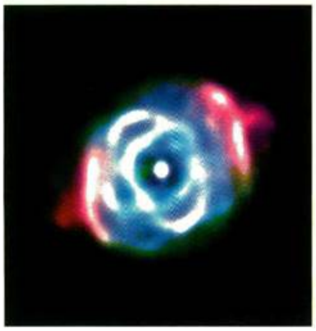
The Last-Minute Eclipse

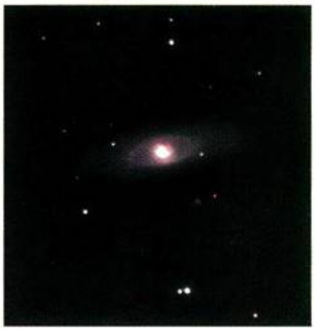
June 10, 2002. Guadalajara, Jalisco, Mexico. I joined an excursion with the Institute of Meteorology and Astronomy of the University of Guadalajara to watch the annular eclipse on the coasts of Jalisco on the Pacific Ocean. Our destination was a virgin beach called "Cruz de Loreto." From where I live in Guadalajara, the trip would take seven hours.

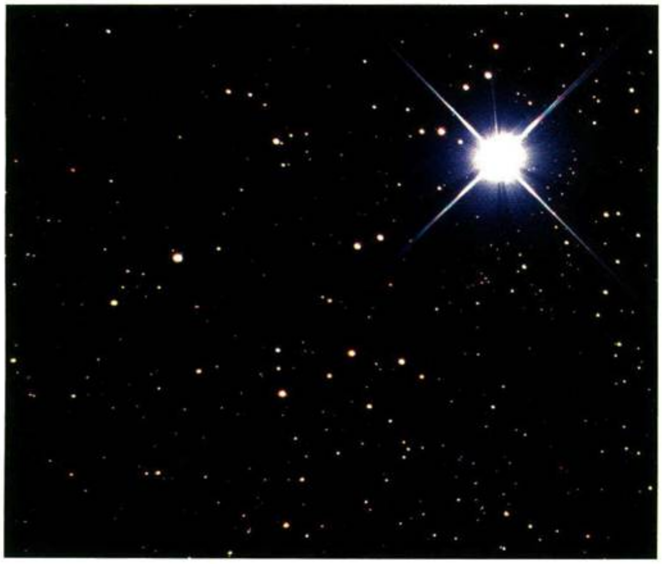
9 A.M. We started our journey by bus. Tropical storm Boris had left the sky covered with dark clouds. It was a long and exhausting trip, as we were straining all the way to look out the window to see if the clouds were gone. We finally arrived at the beach at 7 P.M. More than 200 people were already waiting with cameras, camcorders, and telescopes. Everyone, amateurs and pros alike — even people from NASA — worried about the weather and the clouds blocking the light of the sun from view. Due to the poor conditions, we were all skeptical about whether we would be able to view the eclipse. A few observers even started to refer to the event as "the frustration eclipse."

7:35 P.M. The eclipse began and although the clouds still prevented us from seeing it, we remained patient and never lost hope. I could see two thin lines of sky that were free of clouds, one just below the sun and the other just above the horizon. I told a girl next to me, "If those lines of clarity remain there, we are going to be able to see the









Above: Conjunction of the moon, Venus, and Jupiter

ALLEN HWANG

(Coolpix 950 digital camera, 2-second exposure, taken June 12, 2002, in the Sierra Mountains)

Middle, left: The Cat's Eye Nebula (NGC 6543)

RICH JACOBS

(9.25-inch SCT at f/20, SBIG ST-8E CCD camera, composite exposure)

Middle, right: NGC 4274

PAOLO CANDY

(20-inch Ritchey-Chrétien scope at f/6, DTA CCD camera, taken at the Cimini Astronomical Observatory in Italy)

Bottom: Sirius

LEE C. COOMBS

(10-inch reflector at f/5, Ektachrome 200 film, 10-minute exposure) eclipse when the sun passes through them." We waited for 10 minutes, but before the eclipse reached that first line of clear sky, the clouds covered it once again. Our first ray of hope vanished. The other cloud-free line of sky remained, but the clouds were slowly starting to block it. By this time, many people had given up hope, and started to pack up and leave. Only a few of us remained, holding on to the last ray of hope that we would be able to catch a glimpse of the eclipse.

8:34 P.M. The time of the sunset and the annularity arrived, and still all we could see were clouds. Just as I was about to resign myself to the fact that I would not be able to see the elipse, a miracle happened. In that very thin line free of clouds, where the sky touches the sea, the eclipse suddenly became visible. Everyone screamed and clapped their hands. The few who had their cameras ready began to shoot very fast, getting as many photos as possible, because that sight lasted only two minutes.

The clouds then swallowed the sun and hid the remainder of the eclipse from view. But our short observation of the eclipse made the trip worthwhile. We knew it was a moment we would never forget.

José Luis Cuéllar Cuevas is an avid amateur astronomer in Guadalajara, Jalisco, Mexico.

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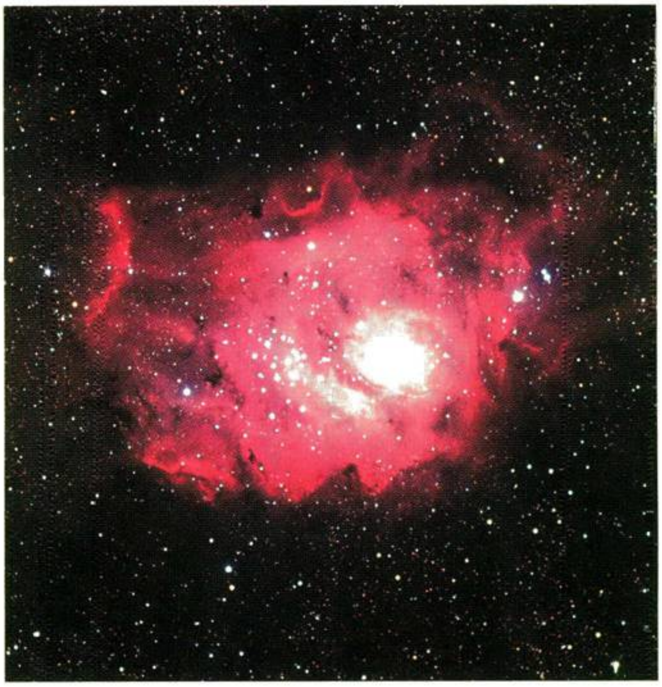
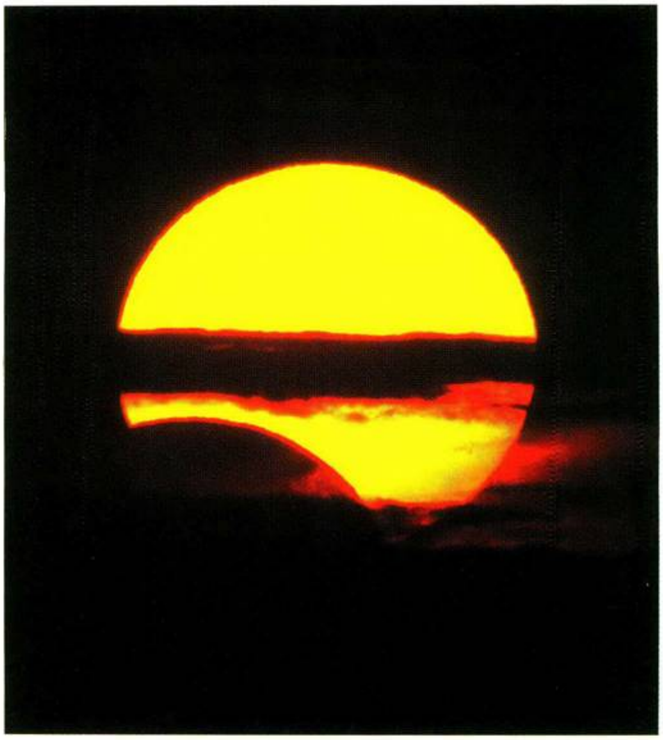


The Lagoon Nebula (M8)

MATT RUSSELL

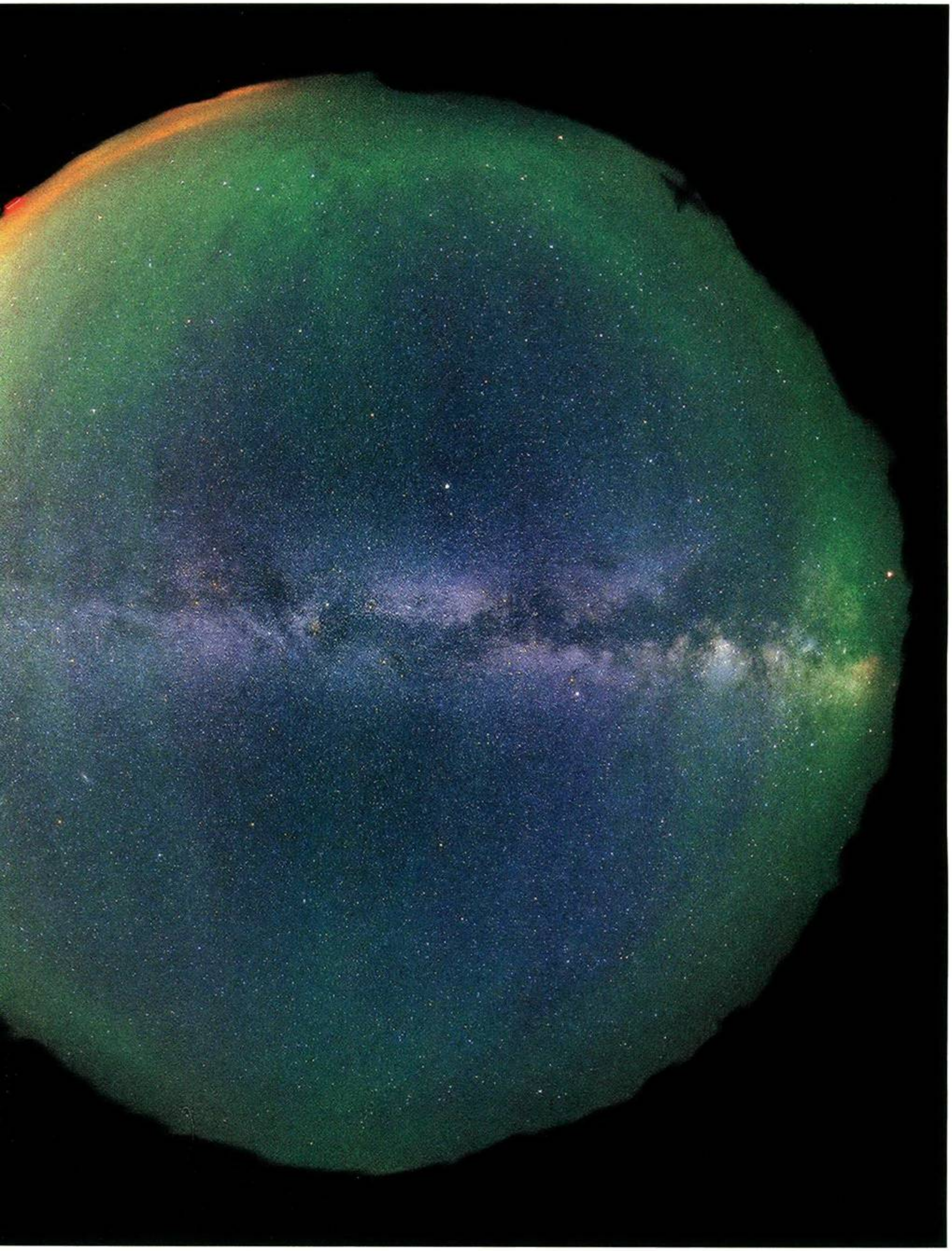
(4-inch apochromatic refractor at f/5, SBIG ST-10E CCD camera, composite exposure)



Partial Solar Eclipse

ROBERT B. SLOBINS

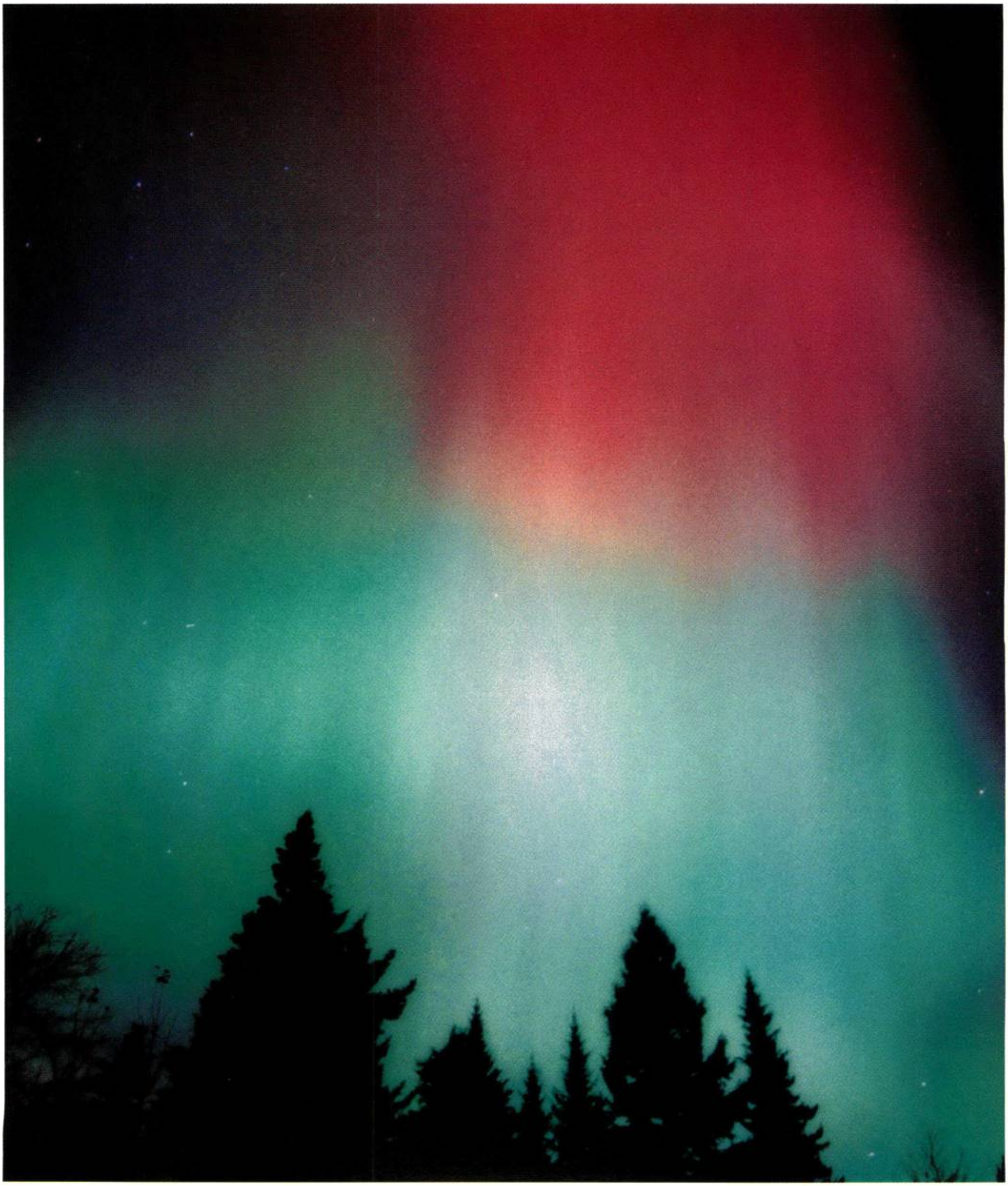
(400mm lens at f/64, Fuji Velvia film, taken on June 11, 2002, in Madison County, Indiana)



Milky Way with Auroral Bands

DOUG ZUBENEL

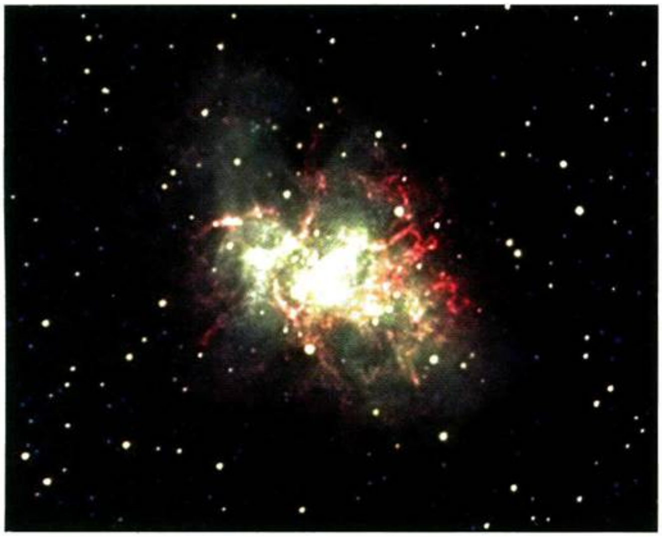
(16mm lens at f/2.8, Fuji 800 film, taken on August 13, 2001, from Linn County, Kansas)



Aurora over Canada

JEAN CHIASSON

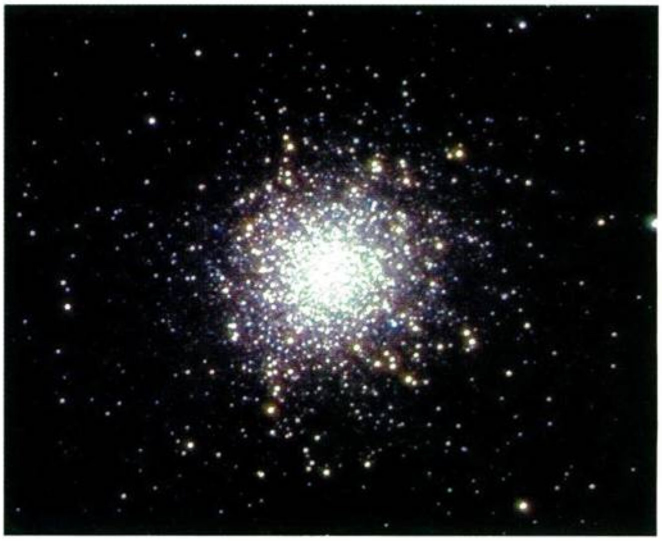
(17mm lens at f/3.5, Fuji 800 Xtra film, 25-second exposure taken from Beauport, Quebec, Canada)



The Crab Nebula (M1)

TED WOLFE

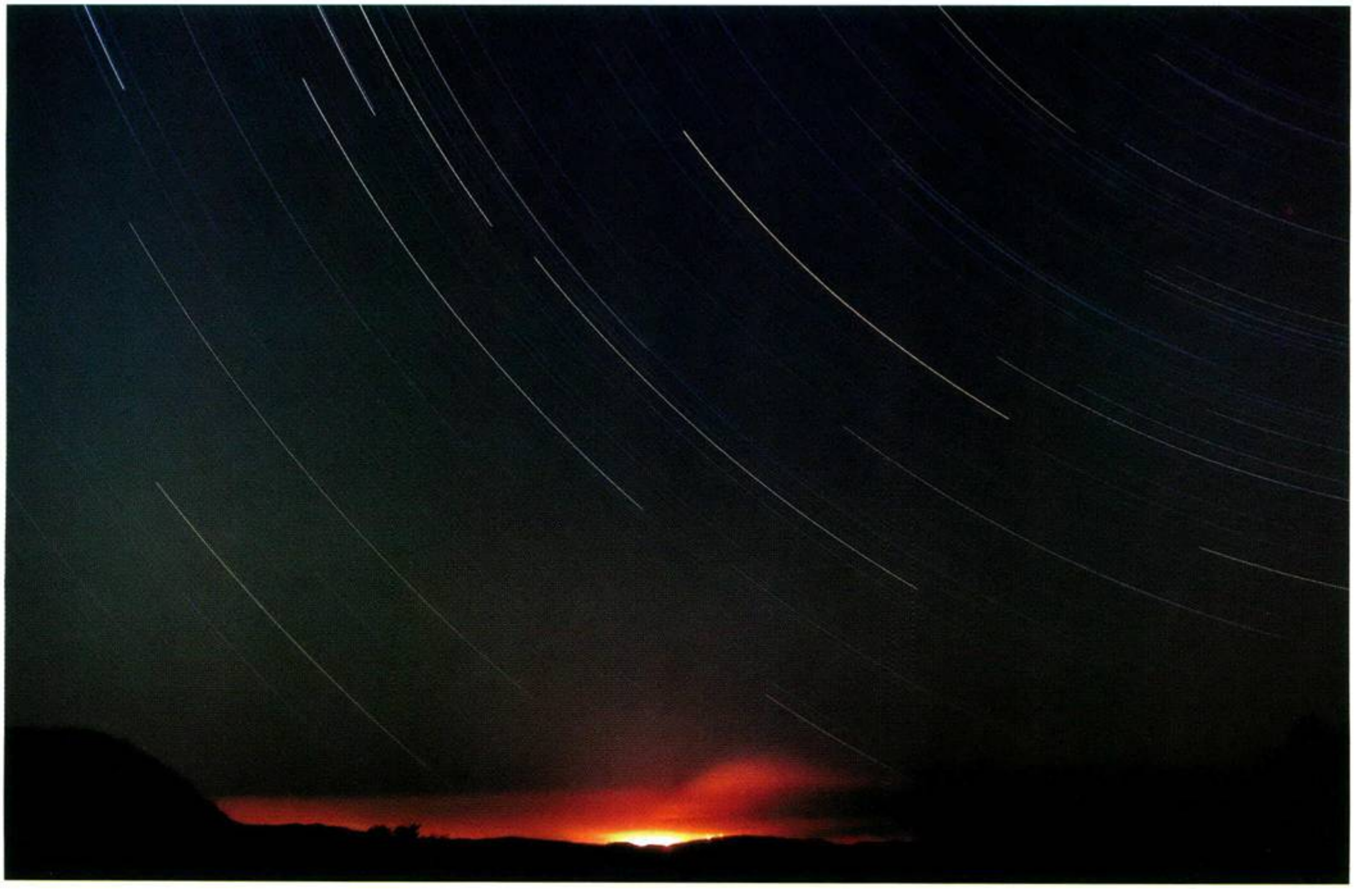
(12.5-inch Ritchey-Chrétien scope at f/7, ST-8E CCD camera, composite exposure)



The Hercules Cluster (M13)

PAUL ZELICHOWSKI

(10-inch reflector at f/4.5, Starlight Xpress CCD camera, composite exposure)



Sequoia Forest Fire and Star Trails

BILL AND SALLY FLETCHER

(90mm lens at f/4, Kodak Pro 400 PPF film, taken June 27, 2000, at Walker Pass, California)

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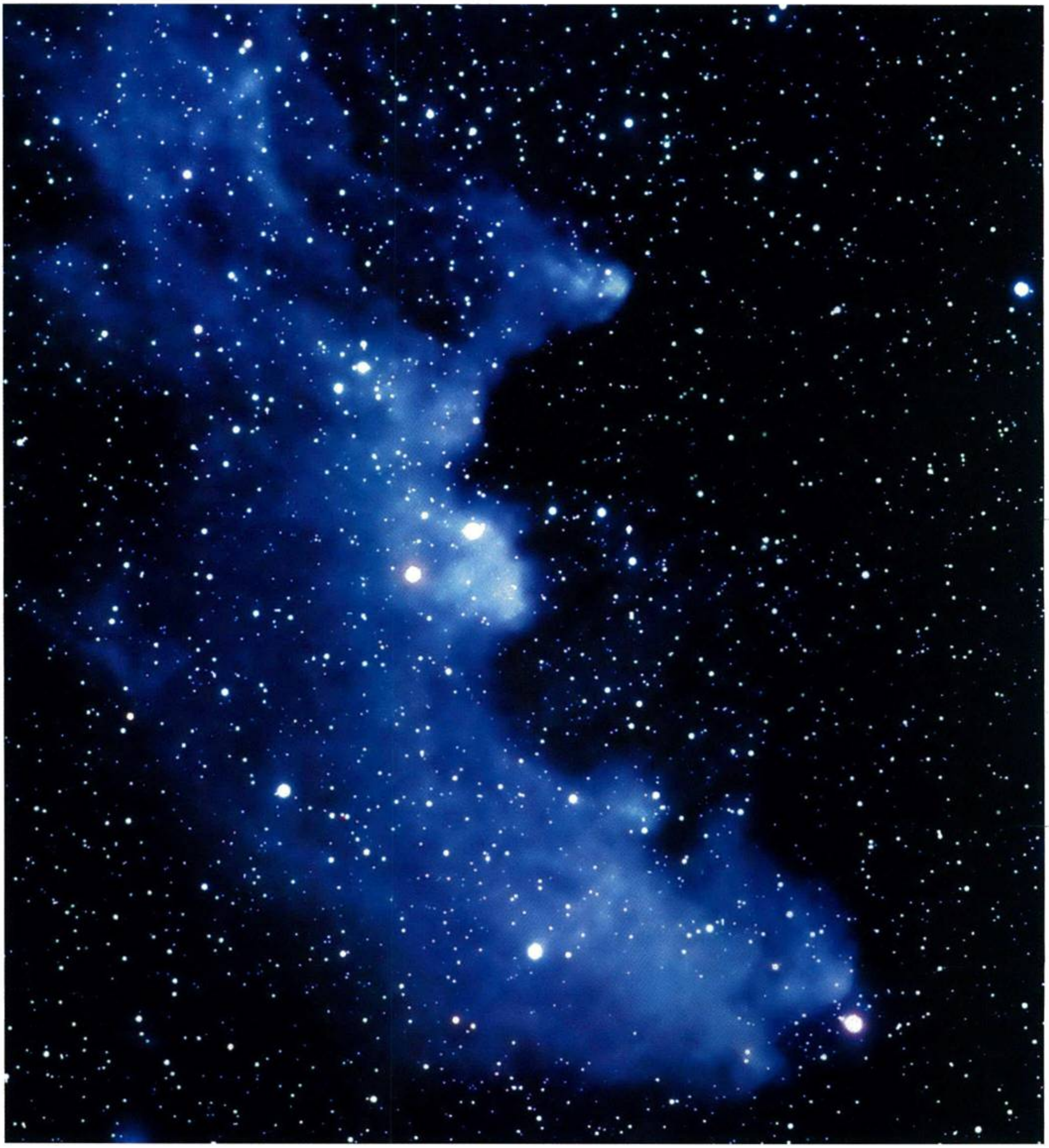

The Witchhead Nebula (IC 2118)

GARY STEVENS

(4-inch refractor at f/5, SBIG ST-8E CCD camera, composite exposure)

This beautiful reflection nebula in Eridanus was captured from Joshua Tree National Park, California.

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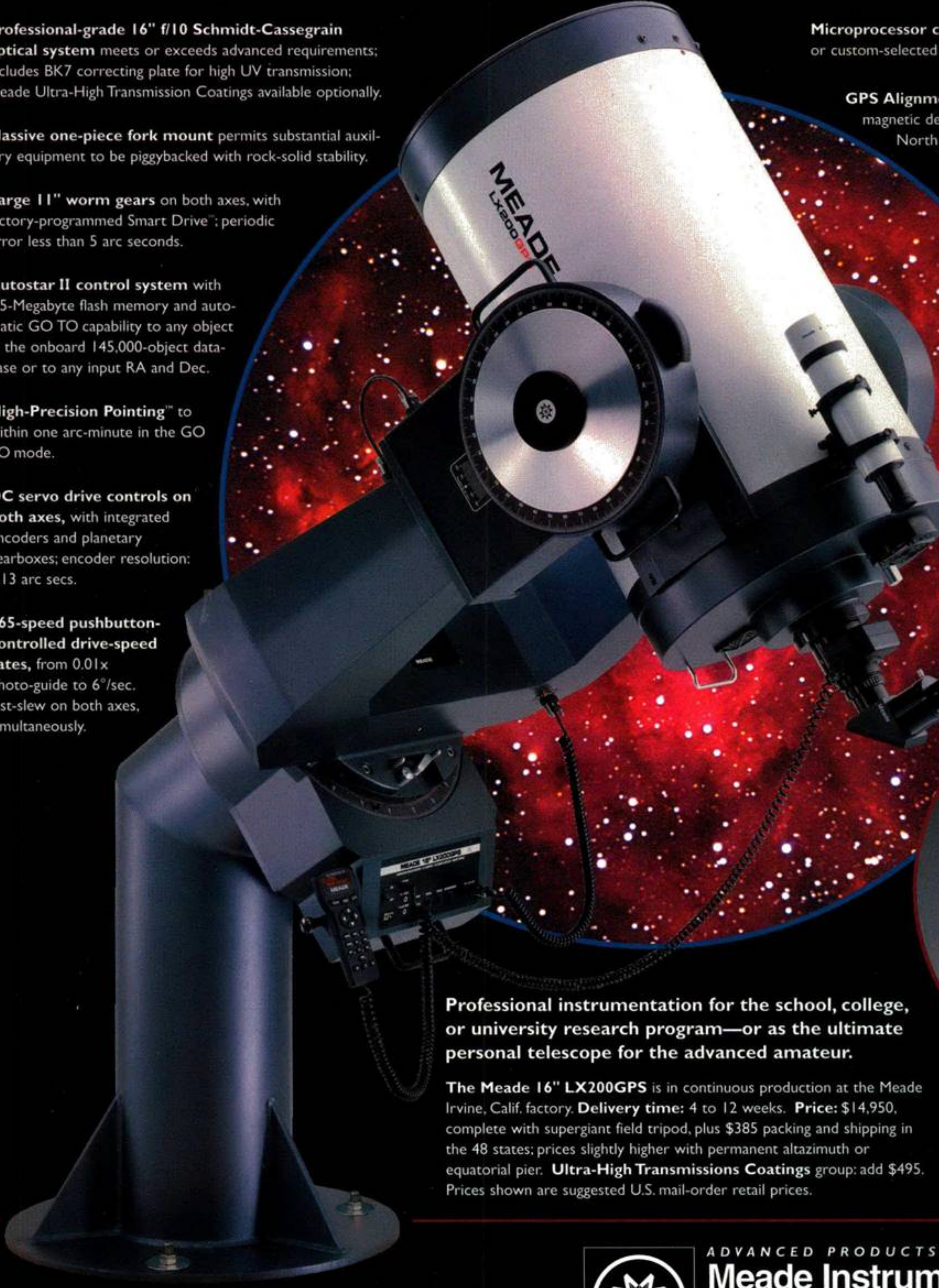

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